September 23, 2020

<u>Ex Parte</u>

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street SW
Washington, DC 20554

Re: *Unlicensed Use of the 6 GHz Band*, ET Docket No. 18-295; *Expanding Flexible Use in Mid-Band Spectrum*, GN Docket No. 17-183

Dear Ms. Dortch:

The Wireless Research Center of North Carolina ("WRCNC") submitted a detailed study to the Commission on June 29, 2020 ("WRCNC Report"), and a presentation on August 18, 2020 ("Body Loss Presentation"), analyzing both far-field and on-body link loss for very-low-power ("VLP") devices in the 6 GHz band (together, the "WRCNC Analysis").[1] We have attached two supplements to the WRCNC Analysis to this letter containing additional detail and information on WRCNC's measurements. Specifically, Appendix 1 to this submission contains additional information from WRCNC regarding the effect of body proximity on antenna gain in the far-field and link-loss measurements on the desired VLP signal. Appendix 2 contains additional illustrations from WRCNC regarding 3D antenna patterns derived from the measurement data. In addition, this letter provides further details on the parameters included in each of WRCNC's tests, as well as explanations of the far-field body loss/antenna gain[2] and on-body link-loss materials contained in the original study and presentation, and in Appendices 1 and 2.

<u>Measurements Included in Each of WRCNC's Tests</u>

The testing conducted by WRCNC included two sets of measurements. First, the testing measured the antenna radiation pattern in three dimensions in an anechoic test chamber (using a spherical set of sensors) for two body-worn devices under test ("DUT")—DUT1 to measure

1 *See* Comments of Apple Inc., Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Microsoft Corporation, NXP Semiconductors, Qualcomm Incorporated, and Ruckus Networks, a business segment of CommScope, ET Docket No. 18-295, GN Docket No. 17-183 (filed June 29, 2020) at Attachment B, Wireless Research Center of North Carolina, On-Body Channel Model and Interference Estimation at 5.9 GHz to 7.1 GHz Band (June 2020) ("WRCNC Report"); Wireless Research Center, WRC Body Loss Testing and Analysis for 6 GHz (Aug. 2020), *as attached to* Letter from Paul Margie, Counsel to Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., and Google LLC, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 18-295, GN Docket No. 17-183 (filed Aug. 20, 2020) ("Body Loss Presentation").

2 As explained in additional detail below, far-field body loss/antenna gain includes the antenna gain pattern, including antenna pattern mismatch, and body effects on the gain pattern.

smartphones and DUT2 to measure eyeglasses ("far-field body loss/antenna gain measurements").[3] Second, the testing measured the link loss between the two body-worn devices, DUT1 and DUT2 ("on-body link loss measurements").[4]

Far-Field Body Loss/Antenna Gain Measurements. The far-field loss/antenna gain measurements included:

(1) Antenna gain pattern for each DUT in the full sphere (e.g. including DUT antenna pattern mismatch) and
(2) Body loss and body effects on the gain pattern.[5]

WRCNC's far-field loss results do not include polarization mismatch loss. The test isolated polarization mismatch losses by measuring the amplitude and phase of the signals in two orthogonal polarizations and then taking the vector sum of the two polarization patterns for each spherical sample point, resulting in a total gain value that is polarization independent.[6] Therefore, when using the far-field loss/antenna gain measurement data in a broader interference analysis, it is appropriate to add an additional polarization mismatch loss value.

Link-Loss Measurements. The link-loss measurements included:

(1) Propagation losses over the given separation distance between DUT1 and DUT2,
(2) Impact of the human body and body effects on the gain pattern,
(3) Antenna pattern mismatch losses between DUT1 and DUT2, and
(4) Polarization mismatch loss between DUT1 and DUT2.[7]

The link-loss measurements did not isolate polarization mismatch loss and used antennas for DUT1 and DUT2 that simulated real-world device antennas. Thus, the resulting link-loss value includes polarization mismatch, and it is not necessary to add any additional polarization mismatch value when analyzing the interaction between the DUT1 and DUT2 devices.

Conducted Power and Total Radiated Power. Appendix 1 explains the WRCNC measurement methodology in detail. The antenna with the known pattern is placed in the anechoic chamber connected to a signal generator and measured by the spherical probes. This procedure is repeated with the DUT, and the DUT's antenna pattern is equal to a reference antenna pattern plus the difference in the received power for each position. Therefore, the conducted power cancels out and does not need to be captured during the far-field tests. [8]

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3 *See* Body Loss Presentation at 4, 5.

4 *See* Body Loss Presentation at 4, 5.

5 *See* Body Loss Presentation at 10; App. 1 at slide 25.

6 *See* Body Loss Presentation at 7, 9; App. 1 at slides 19, 25.

7 *See* Body Loss Presentation at 14; WRCNC Report at 1; App. 1 at slide 25.

8 *See* App. 1 at slides 22-24.

Similarly, TRP was not captured in this report as the purpose of the report was not to evaluate the OTA performance.

Far-Field Body Loss/Antenna Gain Data

The cumulative distribution functions ("CDFs") found in Appendix 1 provide further detail on WRCNC's measurements by disaggregating data presented in the presentation WRCNC made to the Office of Engineering and Technology on August 18, 2020, and including adjustments for the spherical sampling grid. This section explains these data through a selection of the full set of plots found in Appendix 1.

The CDFs for far-field body loss/antenna gain data show "relative gain." WRCNC directly measured the antenna pattern/gain—i.e., the fraction of transmitted energy actually received in each direction in the sphere—for DUT1 and DUT2 in each tested position.[9] This pure antenna gain measurement is representative of the antenna's efficiency in that position. However, the relevant metric from the perspective of analyzing potential interference at an FS is the relative gain, which is the measured antenna pattern minus the maximum antenna gain of the DUT in free space. This is because a device will be certified according to the EIRP of its maximum gain in free space; as a result, the actual RLAN signal level at the FS is captured by the relative gain as defined here. Appendix 1 contains equations explaining the gain measurement and antenna efficiency calculations.[10]

All of the CDFs below that show far-field body loss/antenna gain for DUT1 or DUT2 are adjusted for the spherical sampling grid by using mathematical weighting that accounts for the increased density of measurement samples toward the poles of the sphere.[11] The adjustment results in a uniform sample over the entire sphere by weighting each antenna gain value by Cos(elevation) when producing the CDF.

Figures 1 and 2 show CDFs of the gain for DUT1 and DUT2, respectively, for different elevation angle ranges, relative to the test position of the device. These figures demonstrate that considering a specific range of elevation angles does not significantly change the distribution, particularly for the median values. The dashed line in Figures 1 and 2 shows the gain of the DUT in free space as a reference, to illustrate the amount of total relative gain resulting from body loss/effects relative to antenna pattern absent the body effects.

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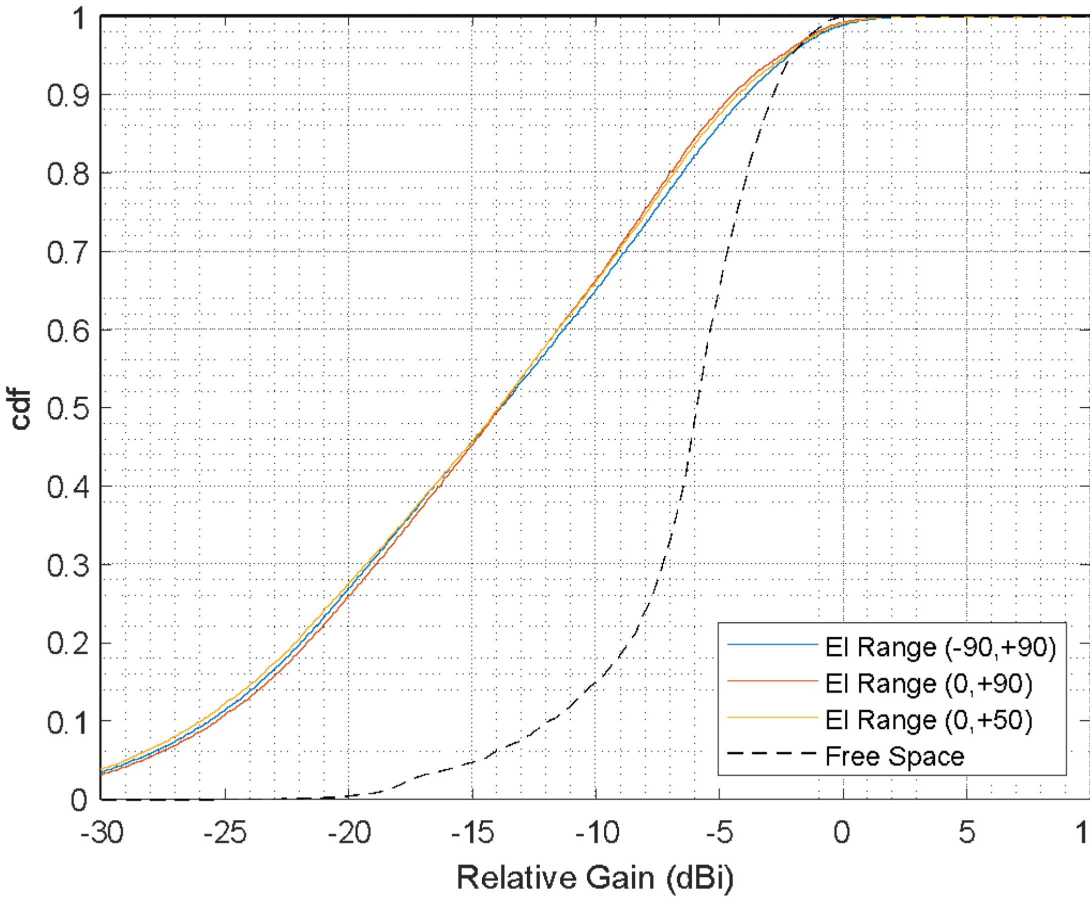
9 *See* App. 1 at slide 22-24.

10 *See* App. 1 at slides 23, 24.

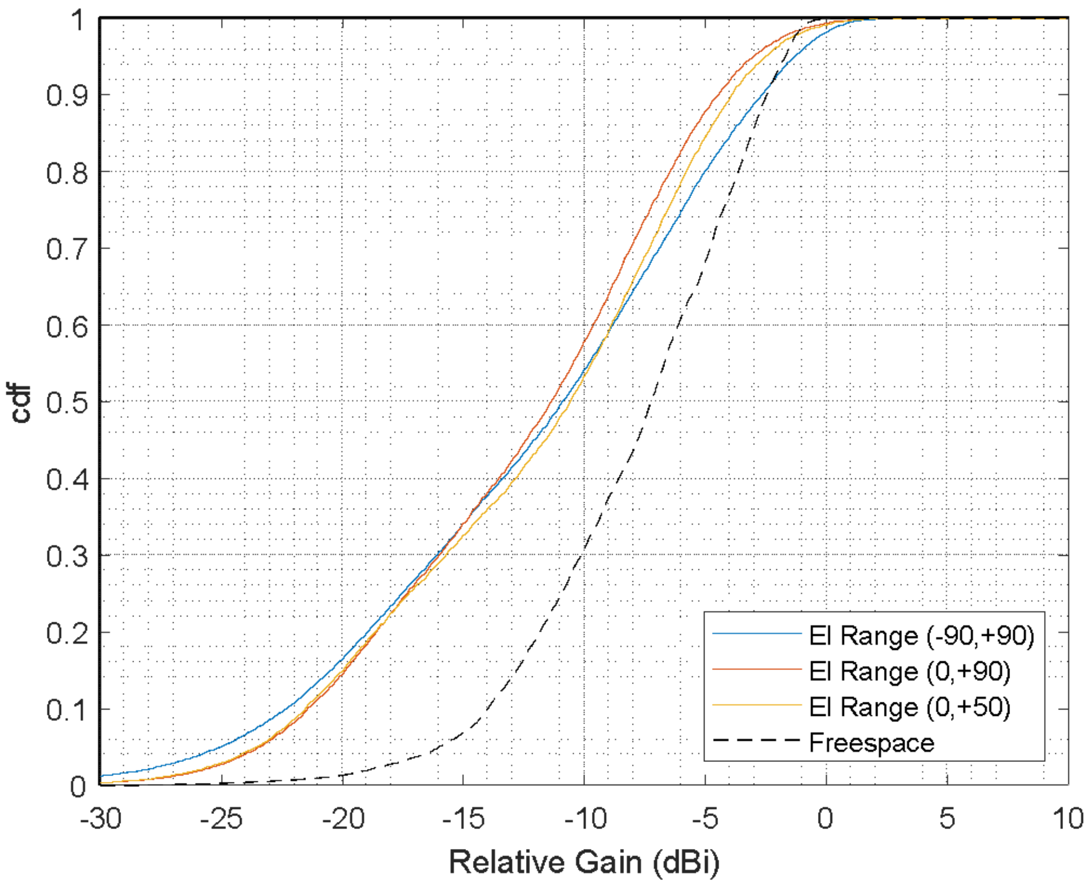
11 *See* Body Loss Presentation at 4, 7 (illustrating the circular configuration of the sensors and the resulting spherical measurement distribution).

Figure 1 – CDF of Relative Gain, DUT1, 6 Subjects, 2 Positions (Left Back Pocket & Backpack) Elevation Range Comparison[12]



[12] App. 1 at slide 2.

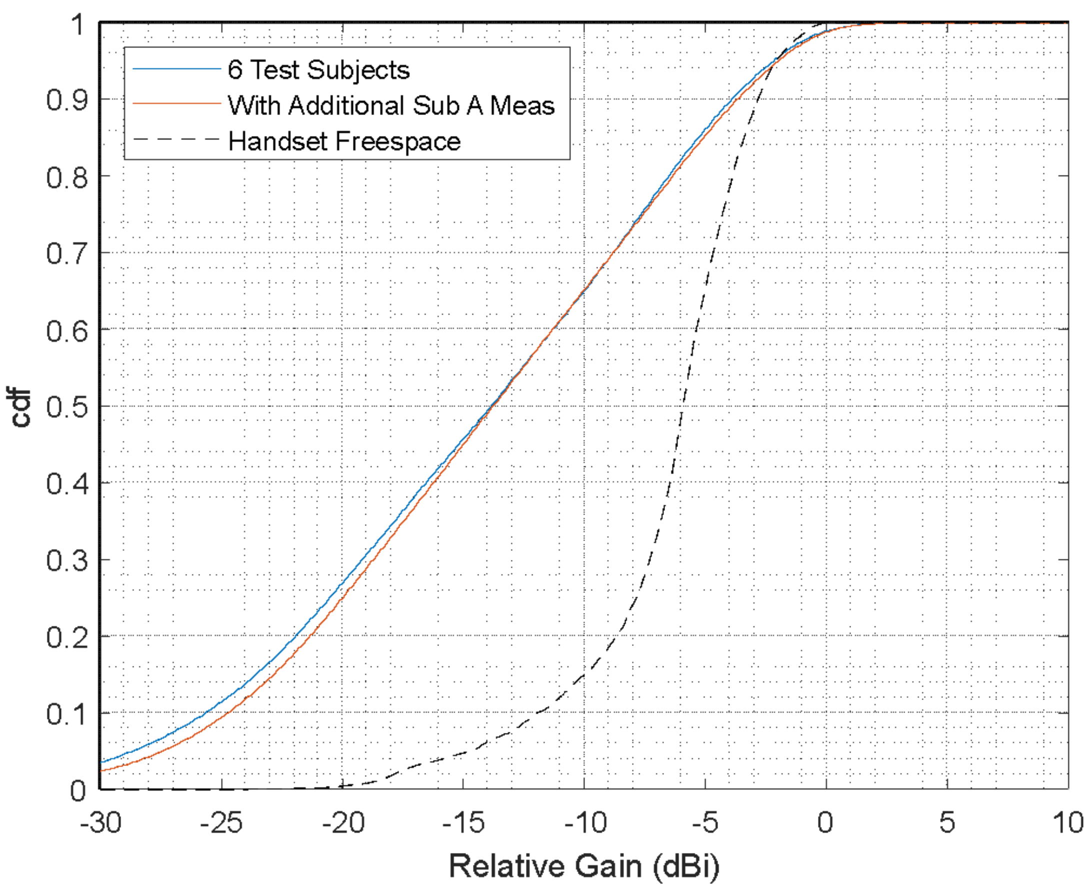
Figure 2 – CDF of Relative Gain, DUT2, 6 Subjects, Forward Pointing, Elevation Range Comparison[13]



13 App. 1 at slide 4.

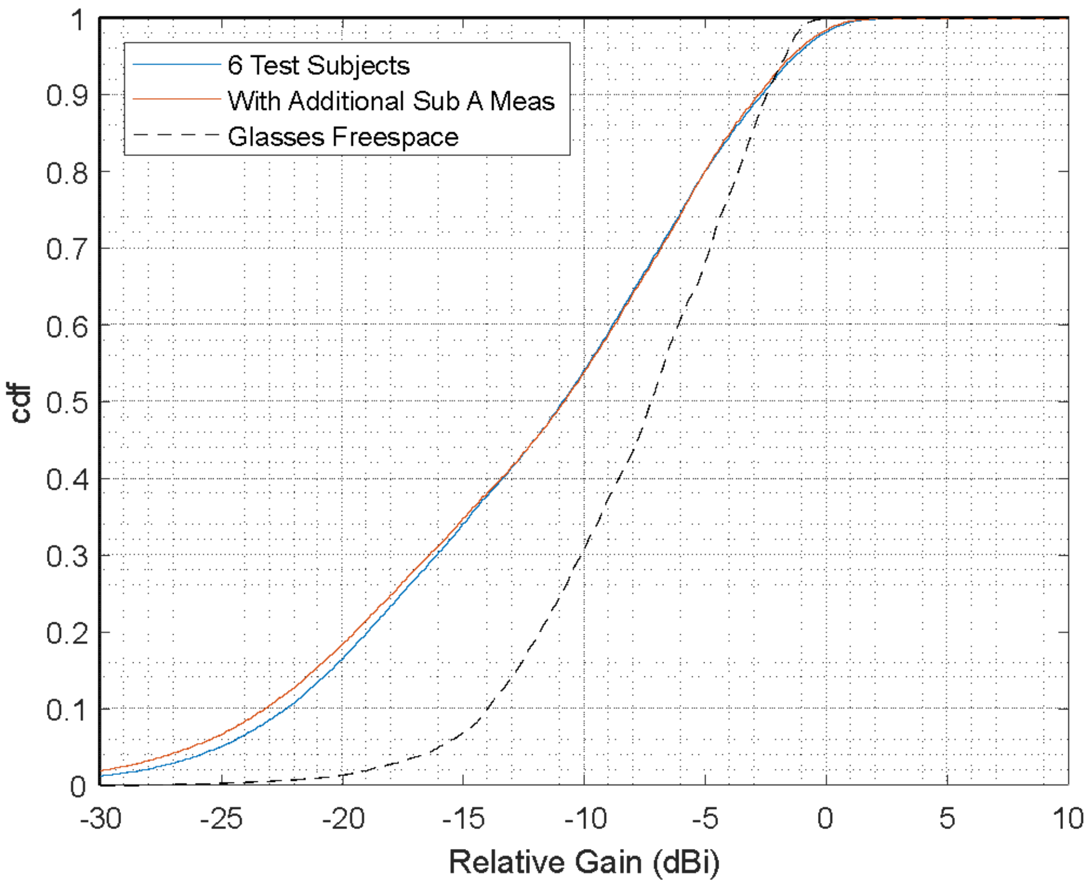
The cumulative antenna gain CDFs presented in the WRCNC Report and the Body Loss Presentation contained additional data for one test subject—Subject A. Subject A participated in additional testing for four additional DUT1 device positions and orientations and two additional DUT2 head pointing directions. All subjects participated in testing with DUT1 in the left back pocket ("test position 4") and in a backpack ("test position 6"). The CDF in Figure 3 illustrates that the additional data associated with Subject A did not significantly affect the results for the DUT1 tests, particularly for the median value. The CDF in Figure 4 illustrates a similar result for the DUT2 measurements.

Figure 3 – CDF of Relative Gain, Handset With and Without additional Subject A Measurements Elevation Range (-90,+90)[14]



[14] App. 1 at slide 10.

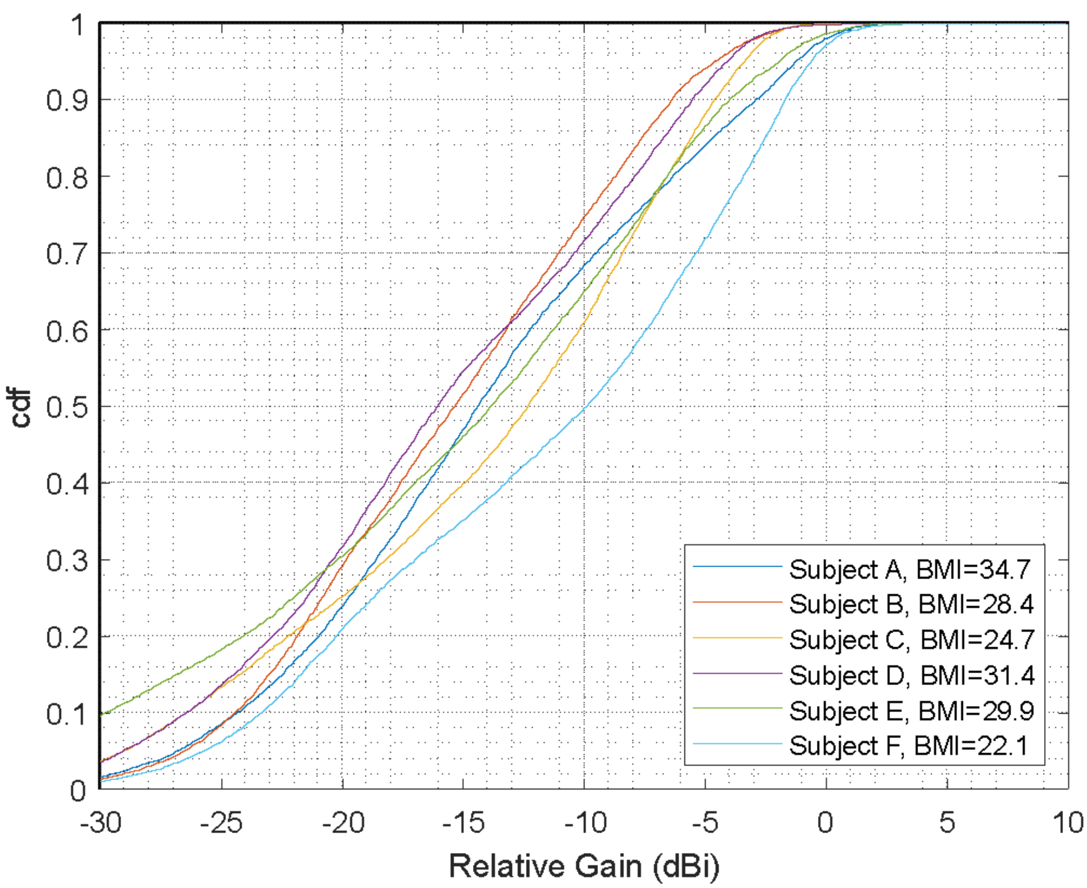
Figure 4 – CDF of Relative Gain, DUT2, With and Without Additional Subject A Measurements Elevation Range (-90,+90)[15]



15 App. 1 at slide 11.

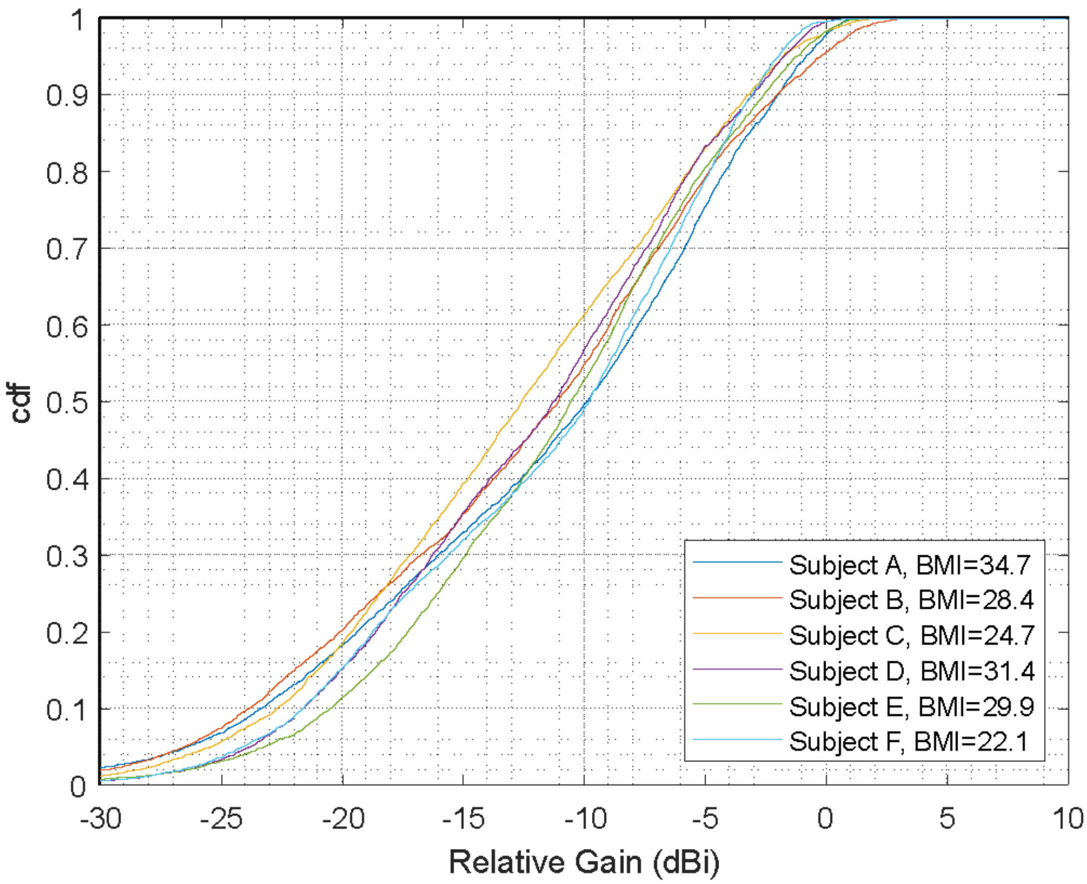
The data for all subjects can also be disaggregated to produce individual CDFs showing the far-field body loss/antenna gain for each subject. Figures 5 and 6 show the results for each subject, for DUT1 and DUT2, respectively. Figure 5 shows the results for DUT1 in the two device positions tested for all subjects—positions 4 (left back pocket) and 6 (backpack). The body mass index ("BMI") values of the six test subjects accurately represent typical BMI values for both men and women in the United States. The test subjects' BMI values were: 34.7 (Subject A, male); 28.5 (Subject B, male); 24.7 (Subject C, male); 31.4 (Subject D, female); 29.9 (Subject E, female); 22.1 (Subject F, female). The most recent nationwide data indicates that the average age-adjusted BMI in the U.S. was 29.1 for men and 29.6 for women.[16] Although the far-field body loss/antenna gain for both DUT1 and DUT2 differed by test subject, the measurements do not show a strong correlation with BMI.

Figure 5 – CDF of Relative Gain, DUT1, Test Subject Comparison, 2 Positions (Left Back Pocket & Backpack), Elevation Range (-90,+90)[17]



[16] U.S. Dep't of Health and Human Services, Center for Disease Control and Prevention, *National Health Statistics Report: Mean Body Weight, Height, Waist Circumference, and*

Figure 6 – CDF of Relative Gain, Glasses Test Subject Comparison, Forward Head Pointing Elevation Range (-90,+90)[18]



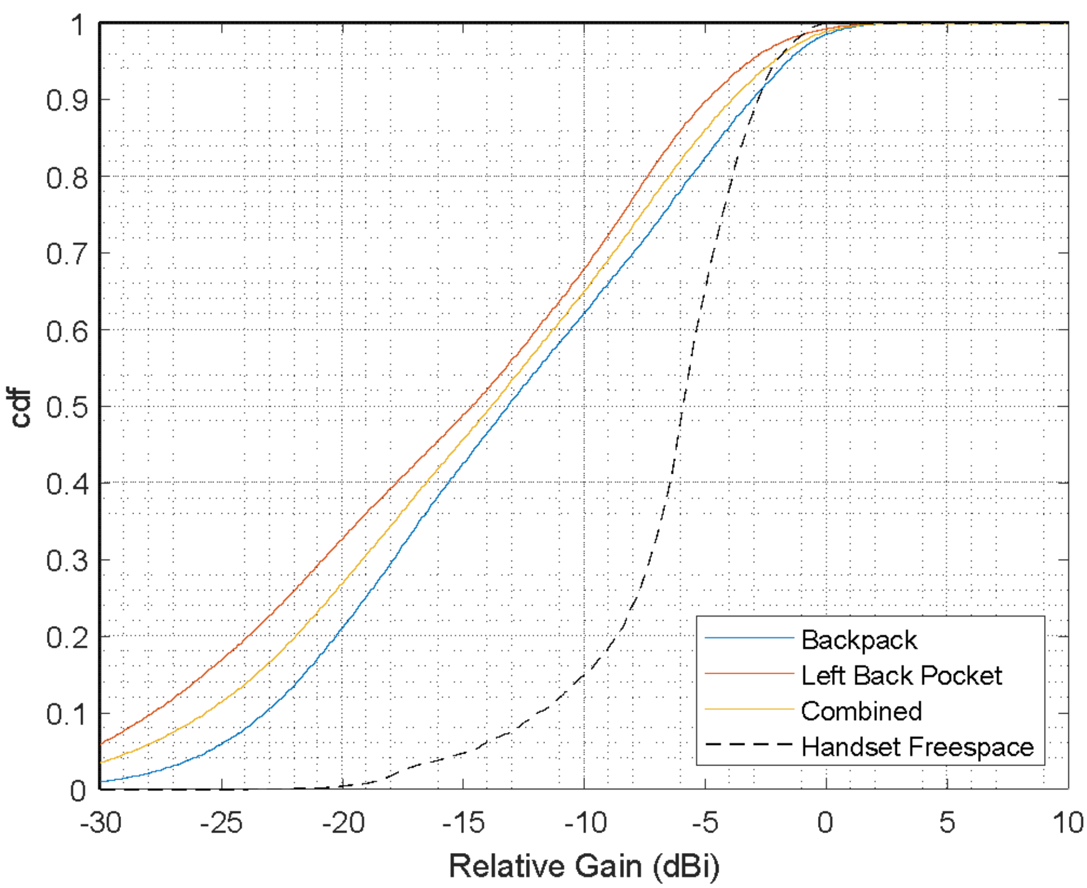
Body Mass Index Among Adults: United States, 1999–2000 Through 2015–2016, No. 122, at Tab. 7 (Dec. 20, 2018), https://www.cdc.gov/nchs/data/nhsr/nhsr122-508.pdf.

17 App. 1 at slide 8.

18 App. 1 at slide 9.

Next, Figure 7 shows the gain for DUT1 measured in two different positions: position 4 (device in the left back pocket) and position 6 (device in the backpack) and demonstrates that the median gain value does not vary significantly based on device position. WRCNC has no data on the relative popularity or likelihood of the various device positions in the real world; thus, WRCNC weighted data from all positions equally to produce the cumulative gain CDFs.

Figure 7 – CDF of Relative Gain, DUT1, All Subjects, Backpack and Left Pocket, Elevation Range (-90,+90)[19]



Finally, the images in the slide deck attached to this filing as Appendix 2 show 3D antenna patterns for all test subjects and all test positions, for both DUT1 and DUT2.

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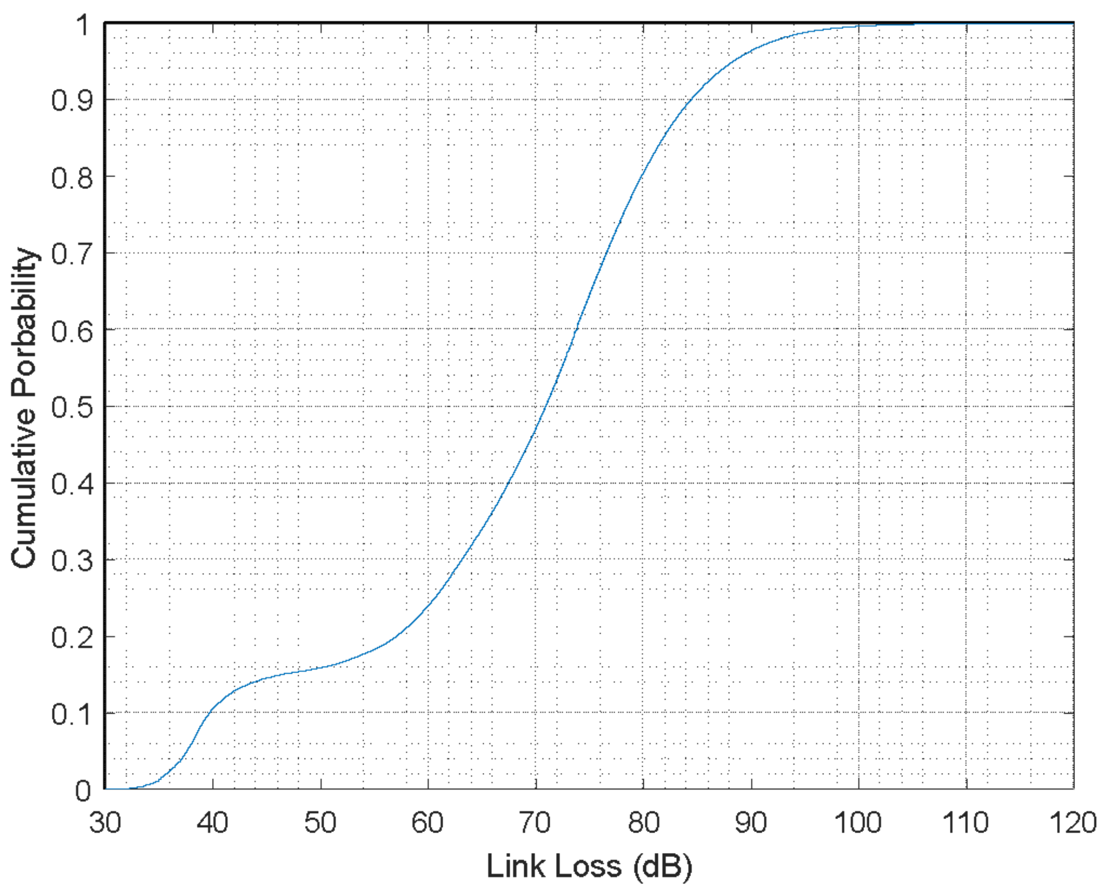
19 App. 1 at slide 13.

Link-Loss Data

For the link-loss measurements, similar to the antenna-gain measurements, Subject A participated in additional test cases for head pointing directions and device orientations not tested for other subjects. Figure 8 shows a cumulative link loss CDF for an equal amount of test cases per subject, as did Figure 24 in the WRCNC Report and Slide 14 in the Body Loss Presentation. Slide 14 in the Body Loss Presentation incorrectly labeled the cumulative link loss CDF as including 108 test cases (i.e., additional Subject A test cases). It did not include the additional Subject A test cases.

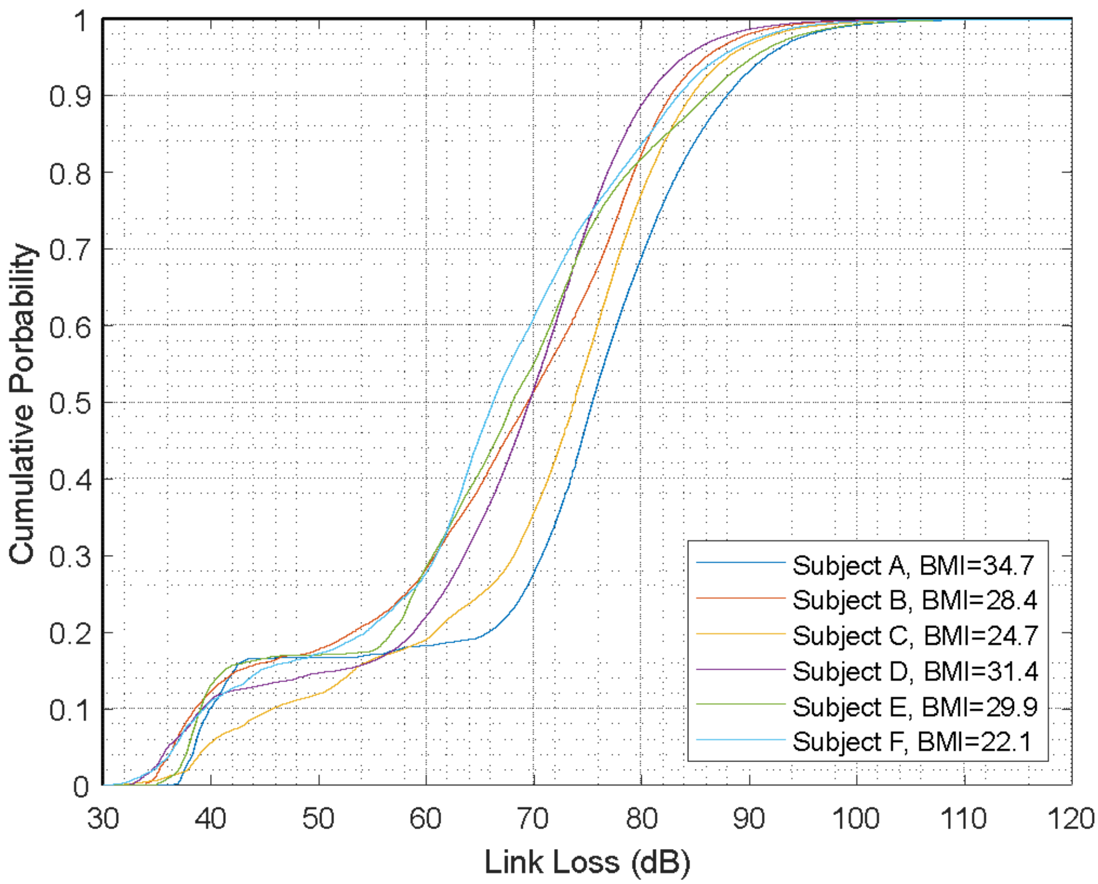
Figure 8 – Link Loss CDF for All Subjects, Six Positions[20]



[20] App. 1 at slide 14.

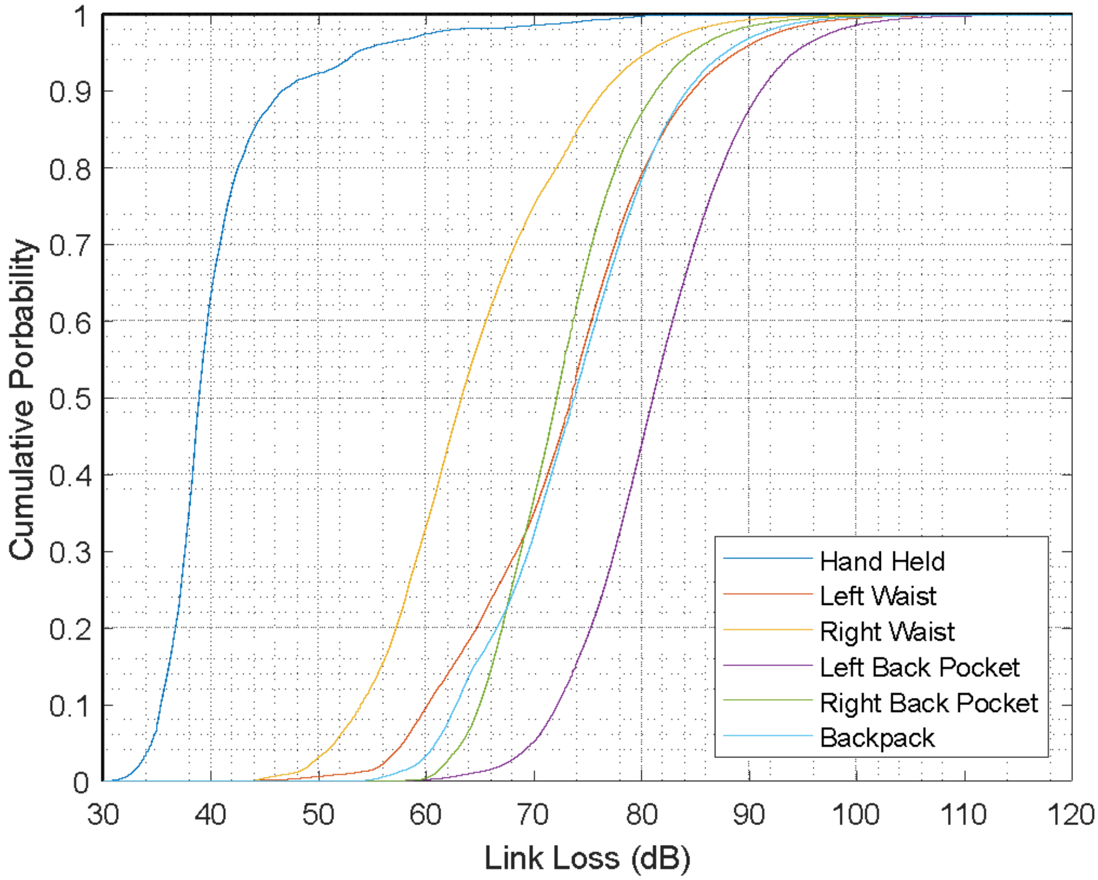
Figure 9 disaggregates the link-loss results by subject, and Figure 10 disaggregates the link-loss results by test position.

Figure 9 – CDF of Link Loss, Test Subject Comparison, 6 Test Positions Combined[21]



21 App. 1 at slide 15.

Figure 10 – CDF of Link Loss, 6 Test Position Comparison, 6 Test Subjects Combined[22]



The effect on link loss of glasses having two antennas instead of the single antenna as included in these measurements can be evaluated by looking at the differences in the link loss between the left waist and the right waist and the left back pocket and the right back pocket. As a best case, if the device would have two antennas, one could expect propagation loss for the left side of the body to be similar to that captured here on the right side. Looking at the median value, this difference in link loss when DUT1 is on the opposite side of the body from the antenna on DUT2 is between 5-6 dB. However, it should be noted that a multiple antenna system is likely to have higher cost and complexity, so it is expected that there will be a variety of designs. Because these devices are not yet on the market, it is unknown what the dominant antenna design would be.

Conclusion

The additional measurement results provided by WRCNC substantiate the analysis provided in both the WRCNC Report and the Body Loss Presentation. Specifically, the results

[22] App. 1 at slide 16.

support the conclusion that 14 dB was a reasonable median value for far-field body loss/antenna gain.

Please do not hesitate to contact the undersigned with additional questions regarding these measurements.

Respectfully submitted,

Apple Inc.
Broadcom Inc.
Cisco Systems, Inc.
Facebook, Inc.
Google LLC
Hewlett Packard Enterprise
Intel Corporation
Microsoft Corporation
Qualcomm Incorporated

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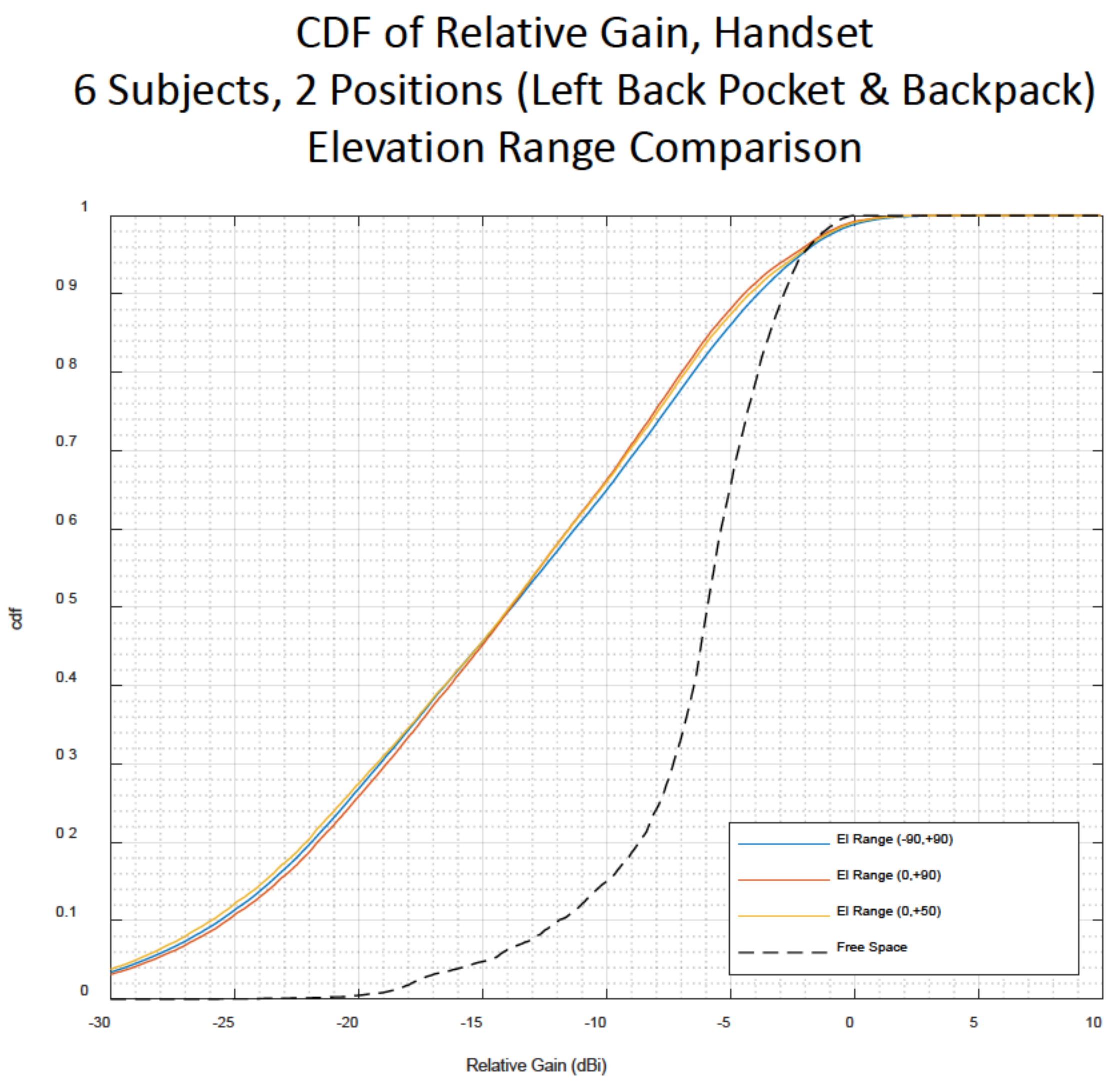
Appendix 1

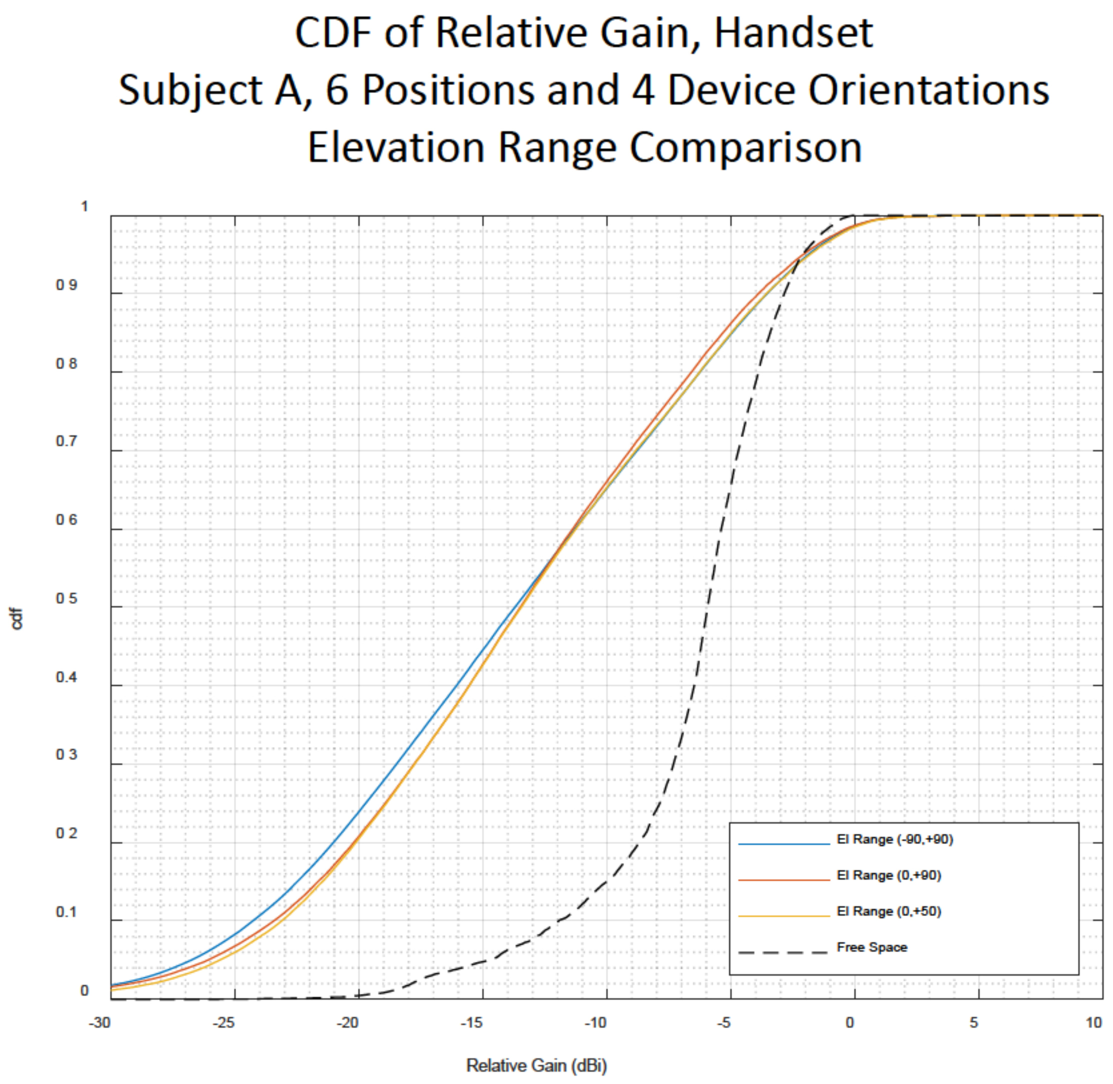
Additional Far-Field and Link-Loss CDF Plots

9/23/2020

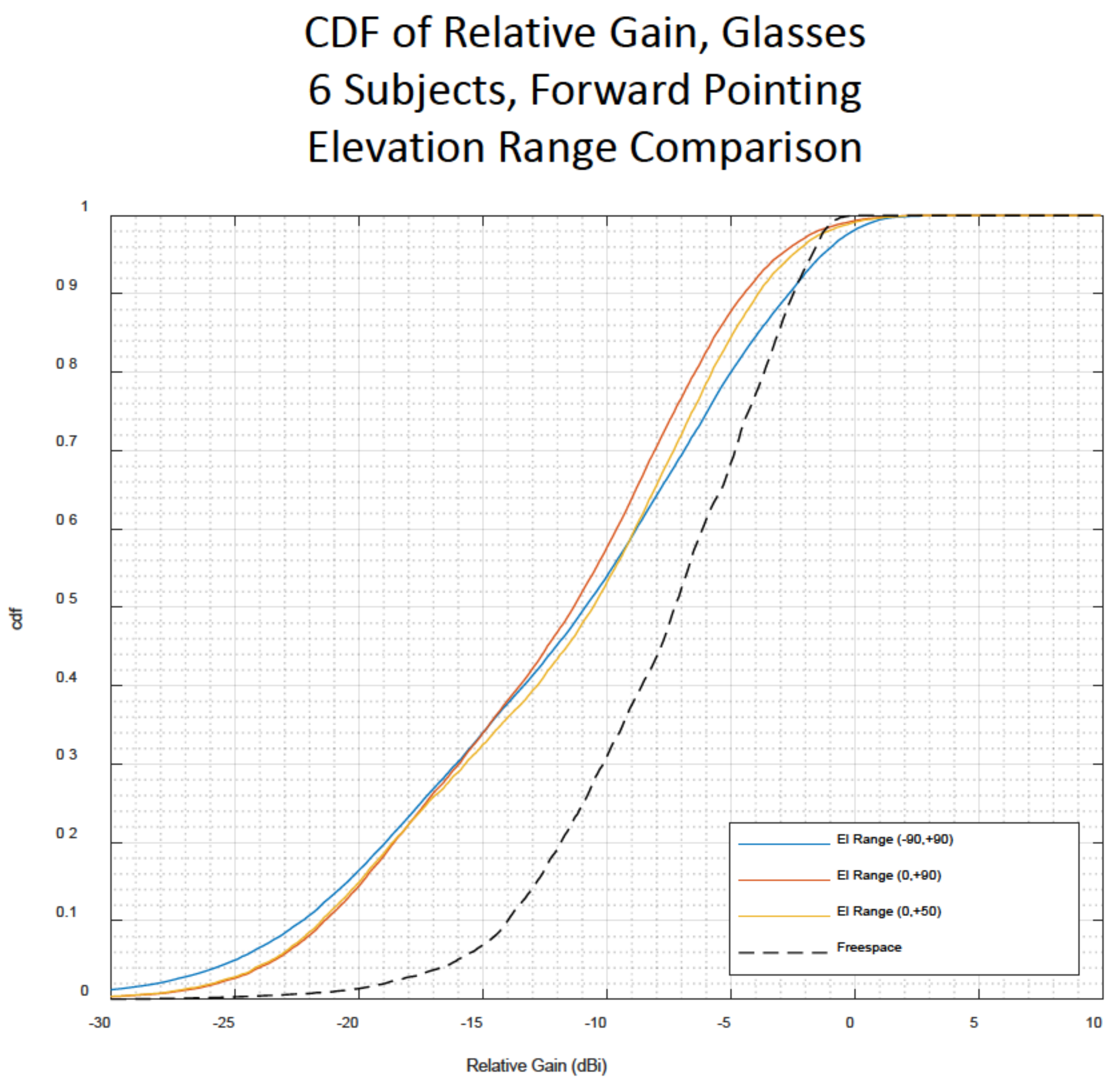
Effects of Elevation Angles, Handset, 6 Subjects, 2 Positions



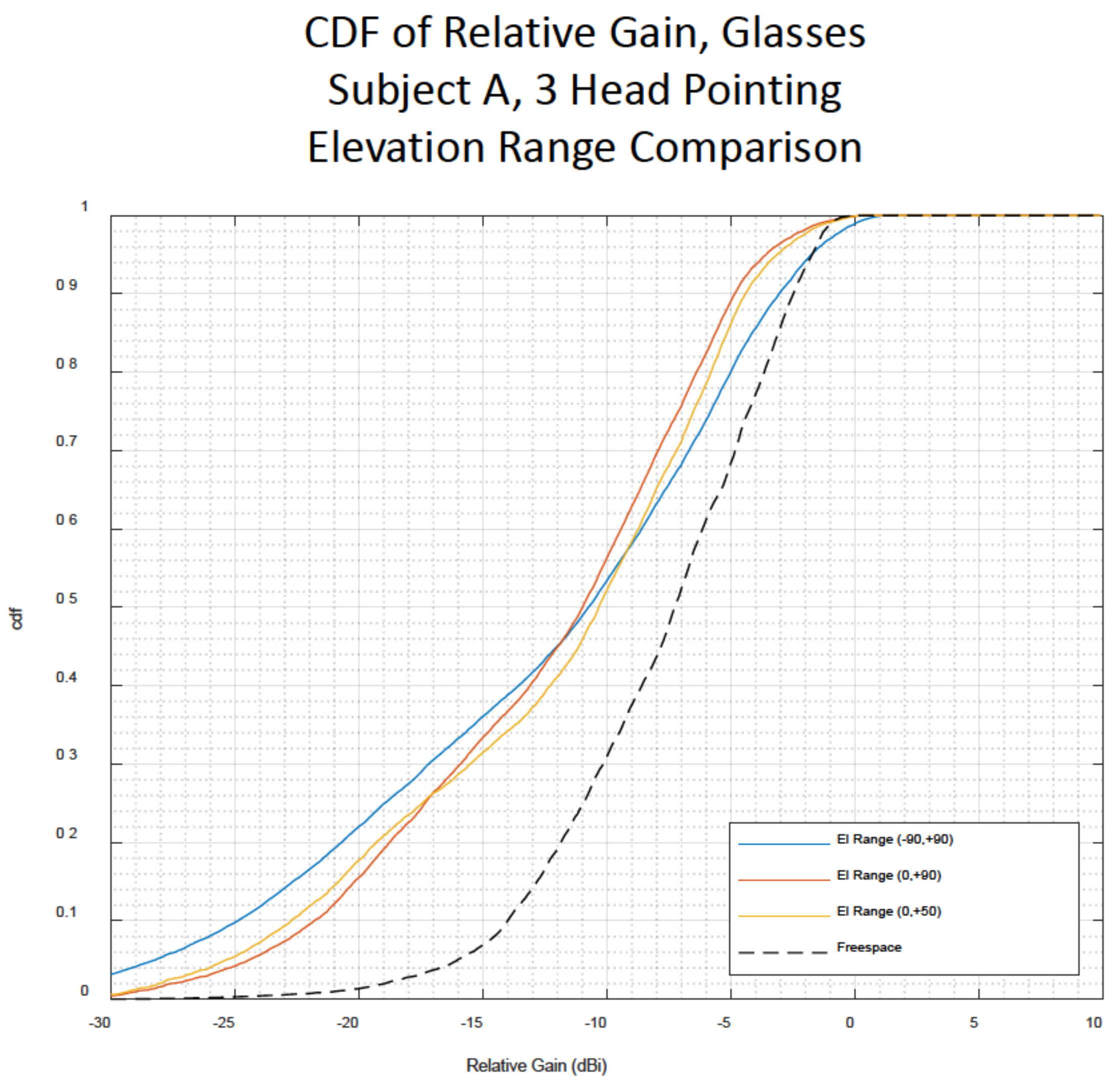
Effects of Elevation Angles, Handset, Subject A Only, 6 Positions



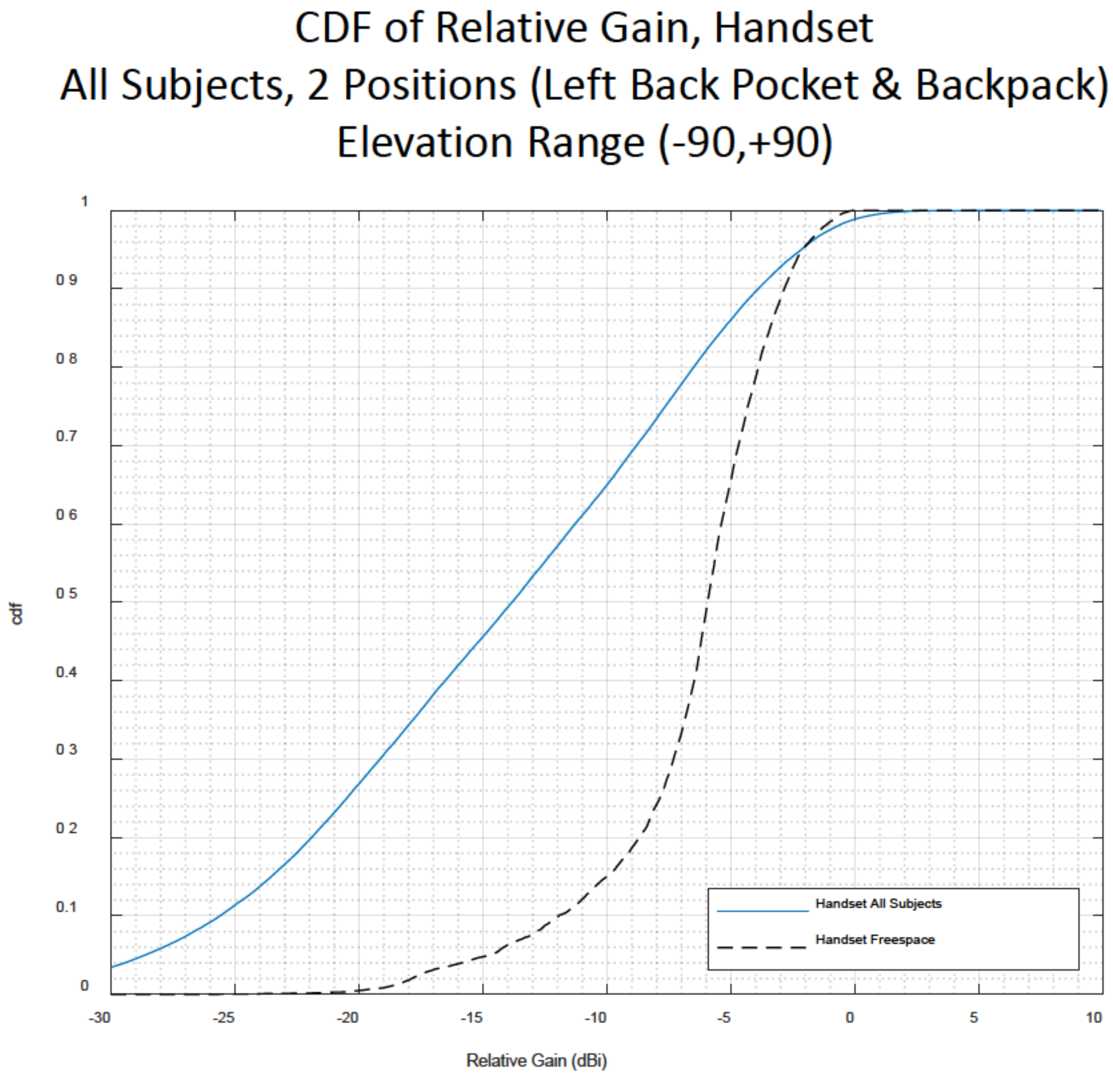
Effects of Elevation Angles, Glasses, 6 Subjects, Forward Head Pointing



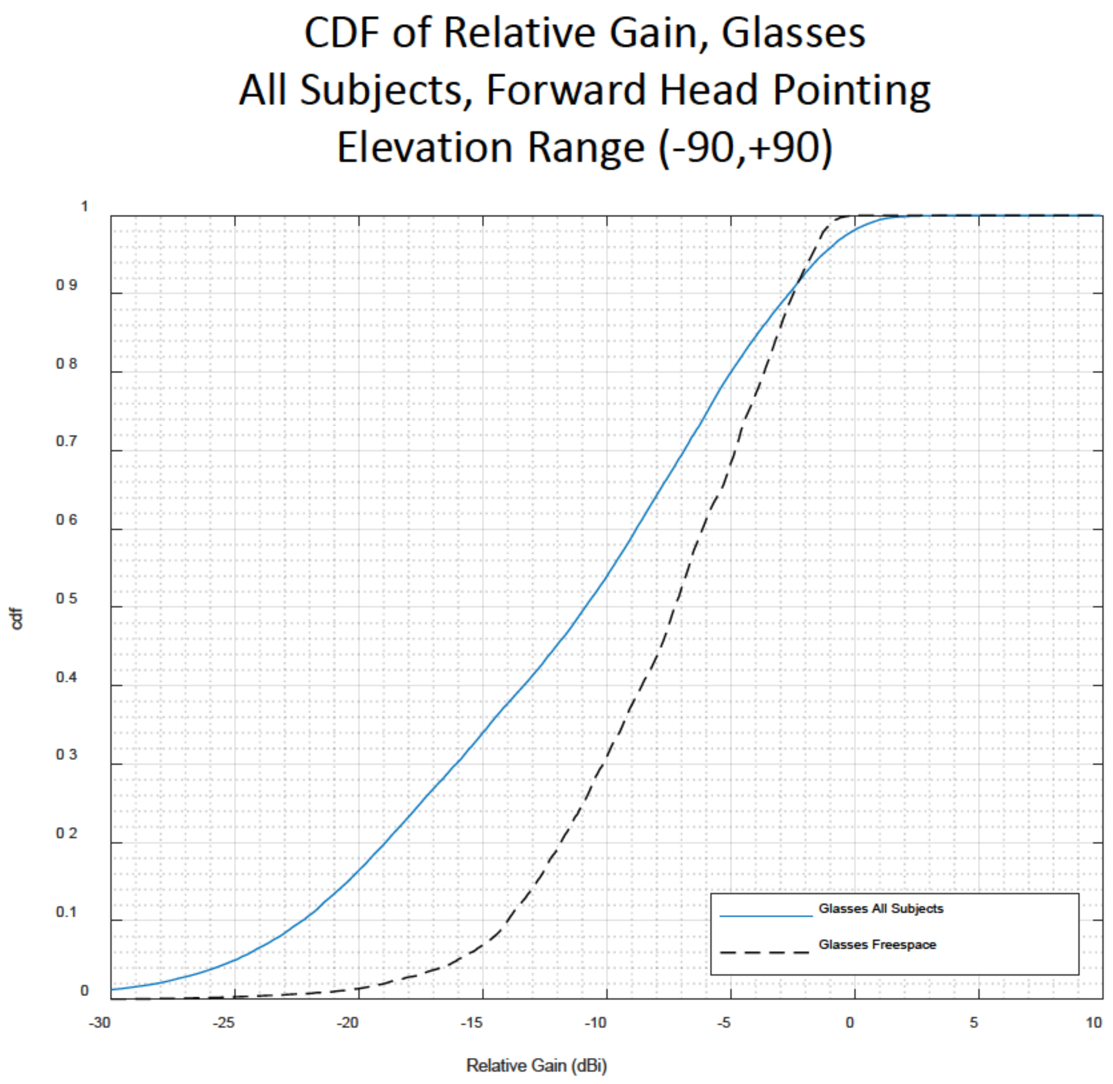
Effects of Elevation Angles, Glasses, Subject A Only, 3 Head Pointing



CDF of Handset, All Subjects, 2 Positions

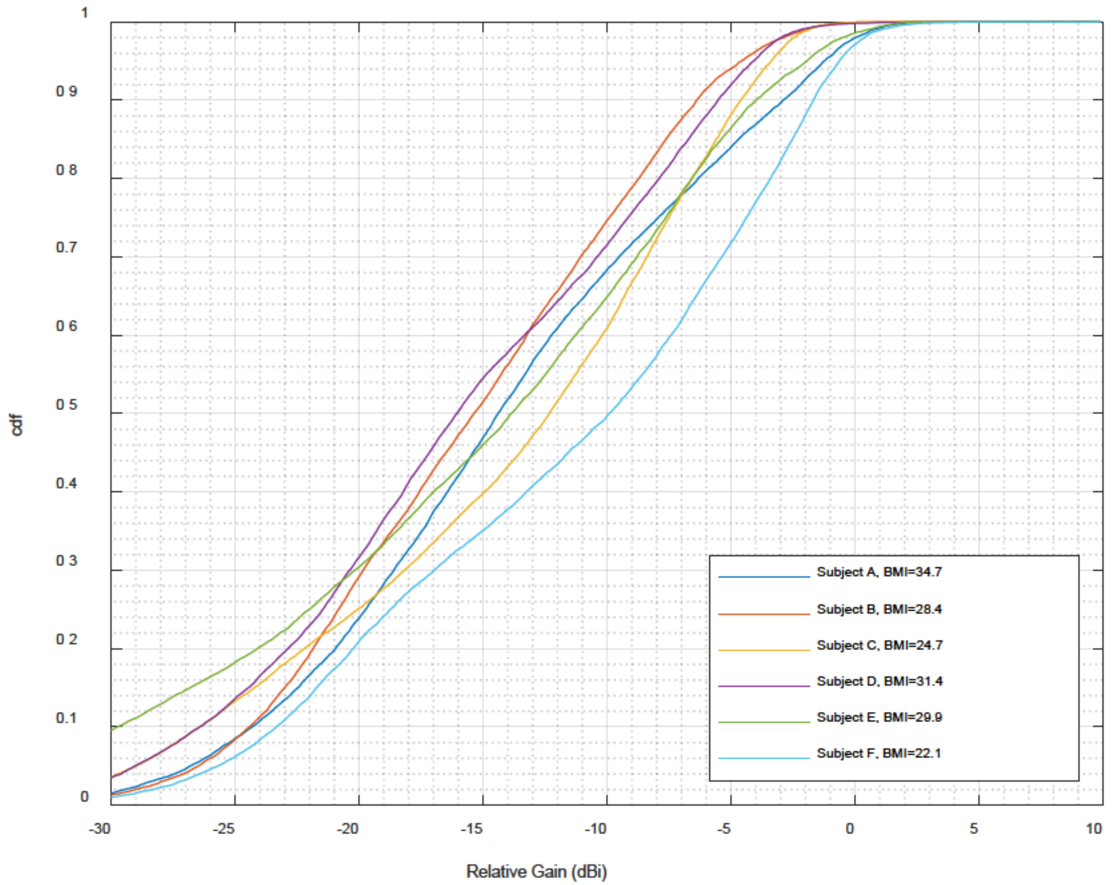


CDF of Glasses, All Subjects, Forward Head Pointing



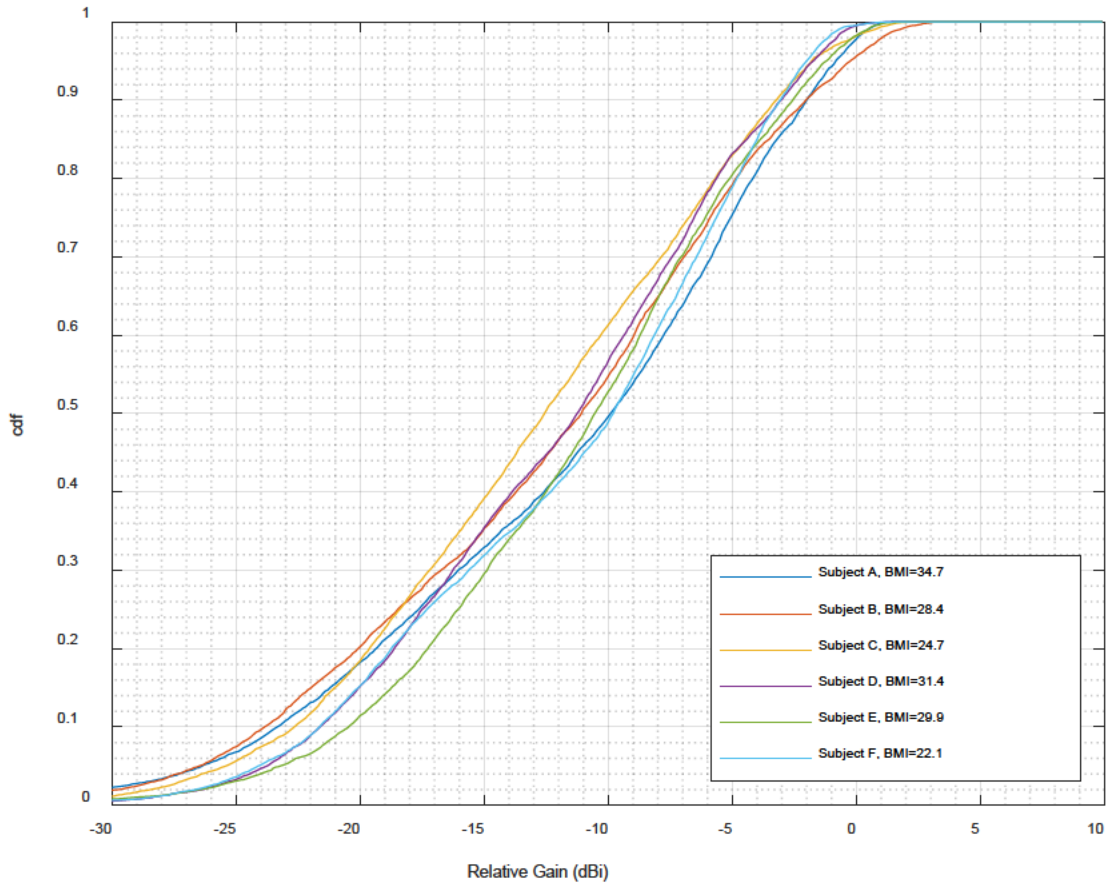
BMI Sensitivity, Handset on Test Subjects

CDF of Relative Gain, Handset
Test Subject Comparison, 2 Positions (Left Back Pocket & Backpack)
Elevation Range (-90,+90)



BMI Sensitivity, Glasses on Test Subjects

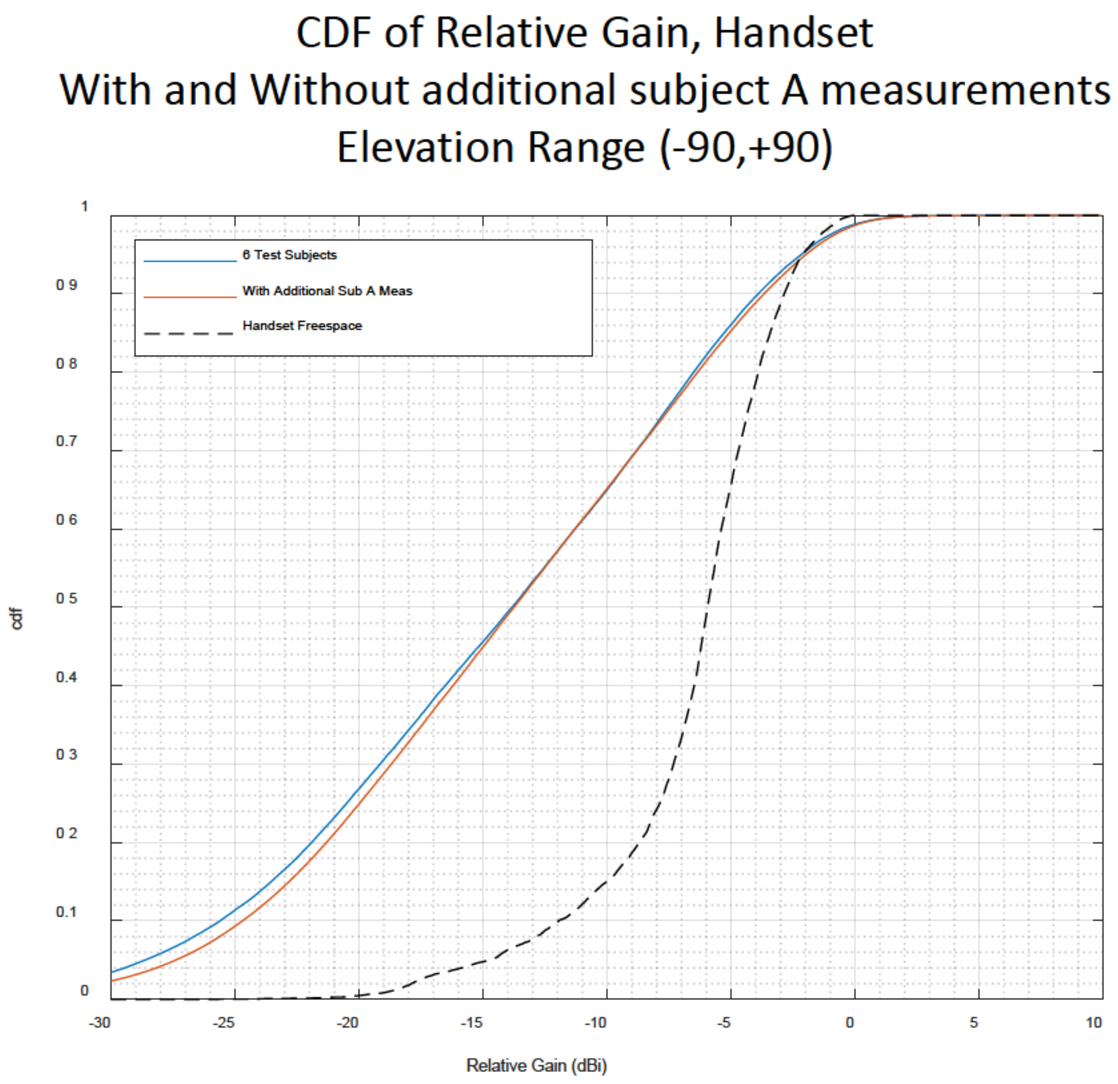
CDF of Relative Gain, Glasses
Test Subject Comparison, Forward Head Pointing
Elevation Range (-90,+90)



Median Relative Gain CDF Values

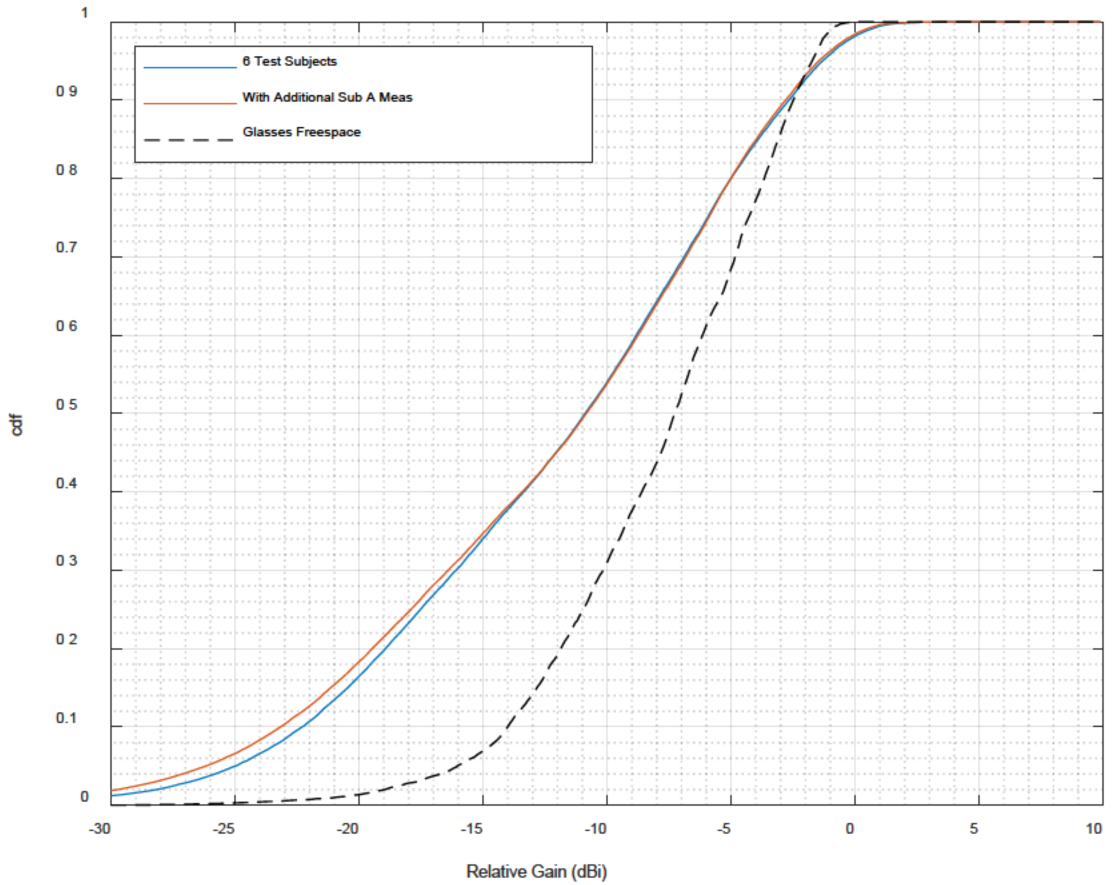
Test Subject	(-90,+90)	(0,+90)	(0,+50)
A	-9.9	-10.2	-9.8
B	-11.0	-12.3	-10.5
C	-12.5	-13.2	-12.6
D	-11.2	-11.5	-11.2
E	-10.5	-11.0	-10.2
F	-9.8	-10.0	-9.5

Additional Subject A Measurement Effects, Handset

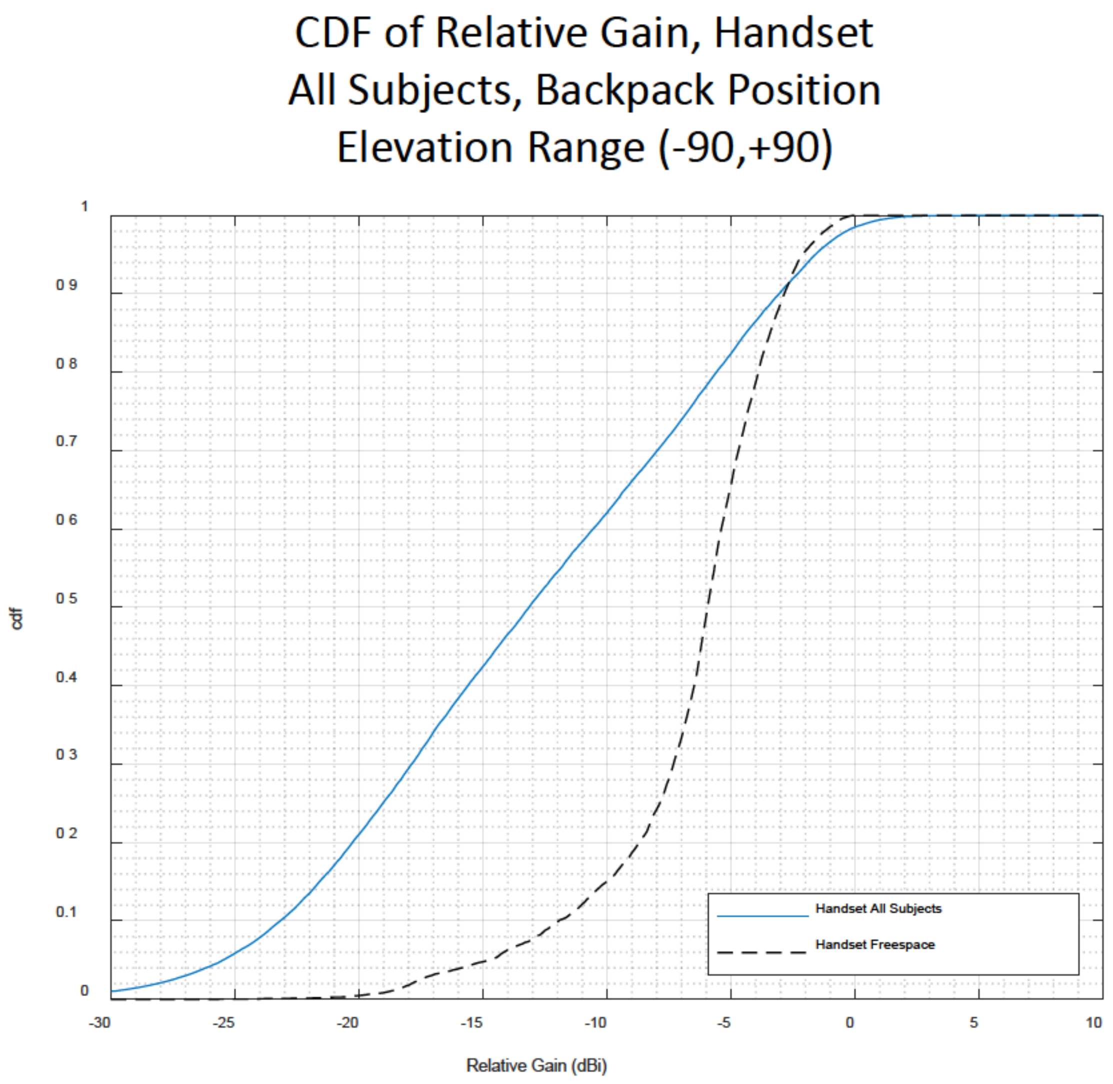


Additional Subject A Measurement Effects, Glasses

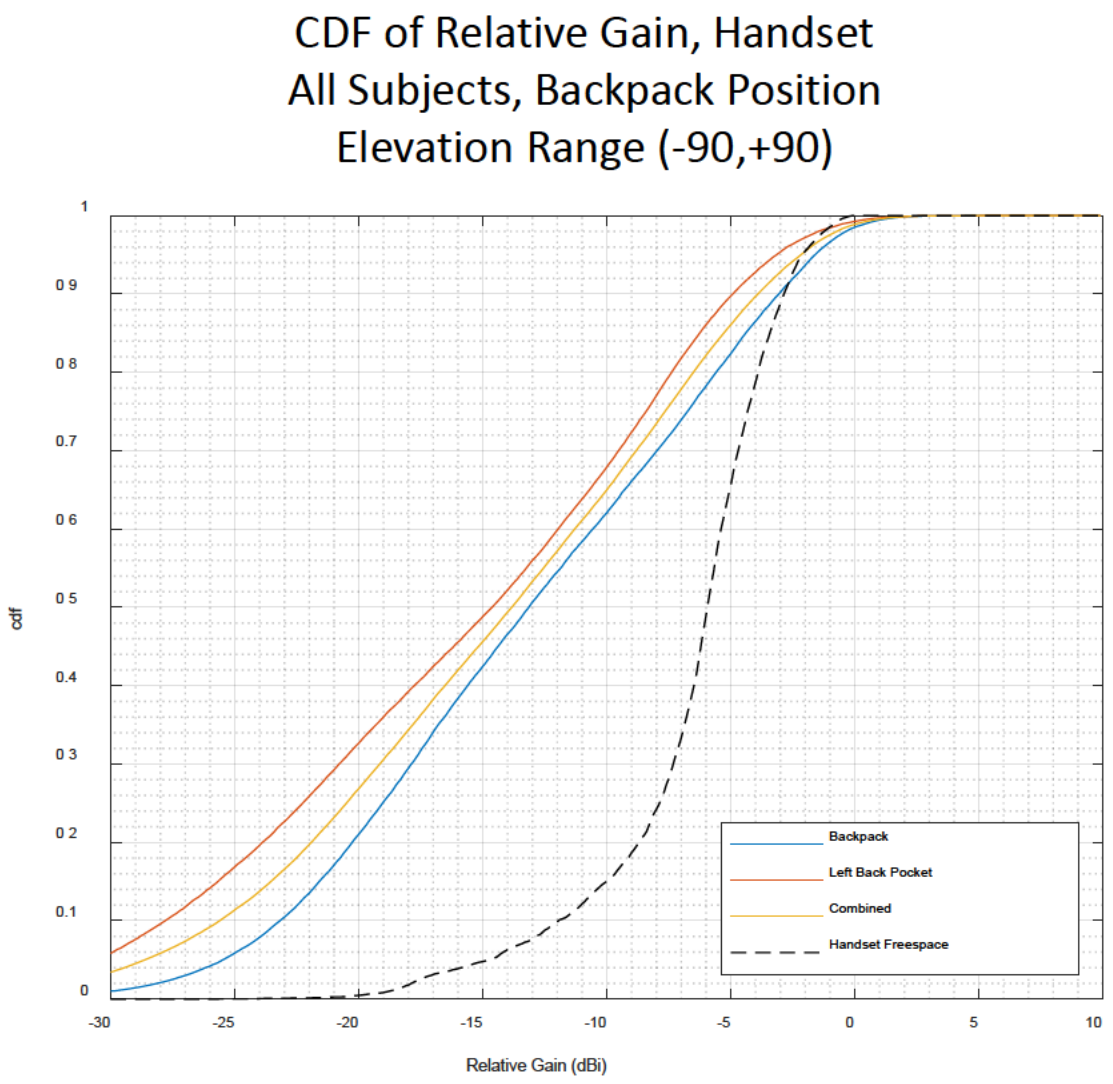
CDF of Relative Gain, Glasses
With and Without additional subject A measurements
Elevation Range (-90,+90)



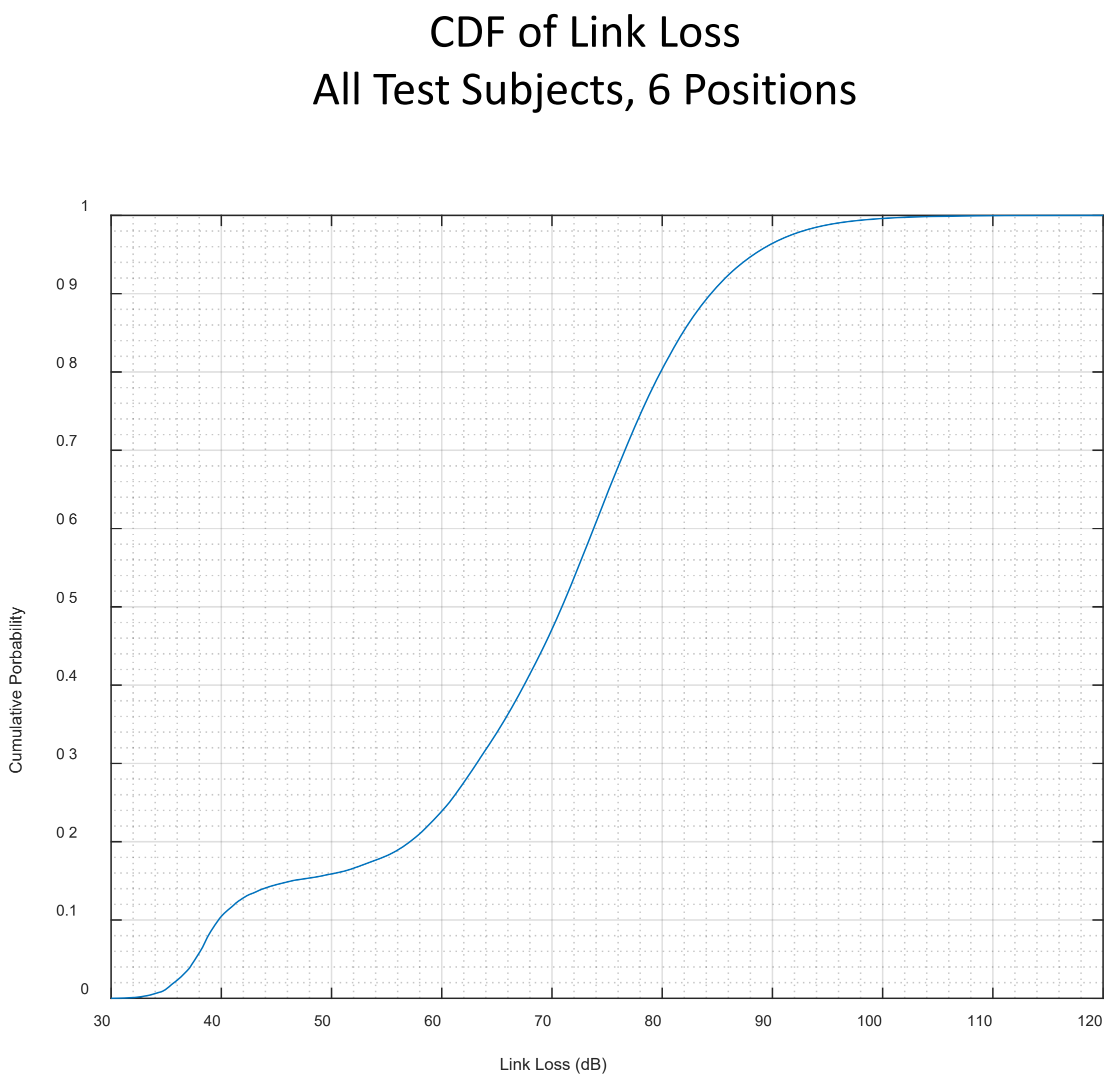
CDF of Backpack Position



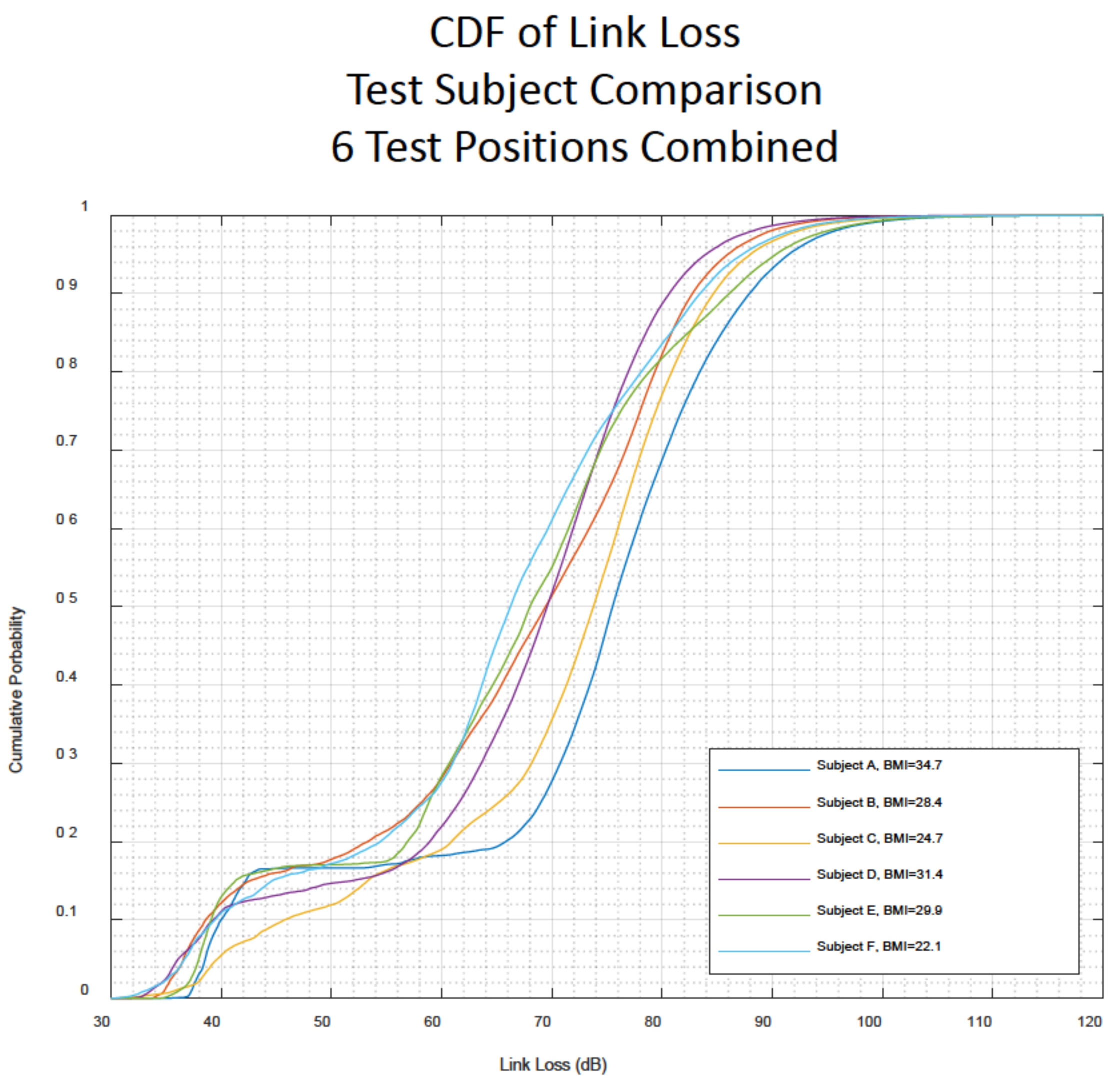
Backpack vs Left Back Pocket



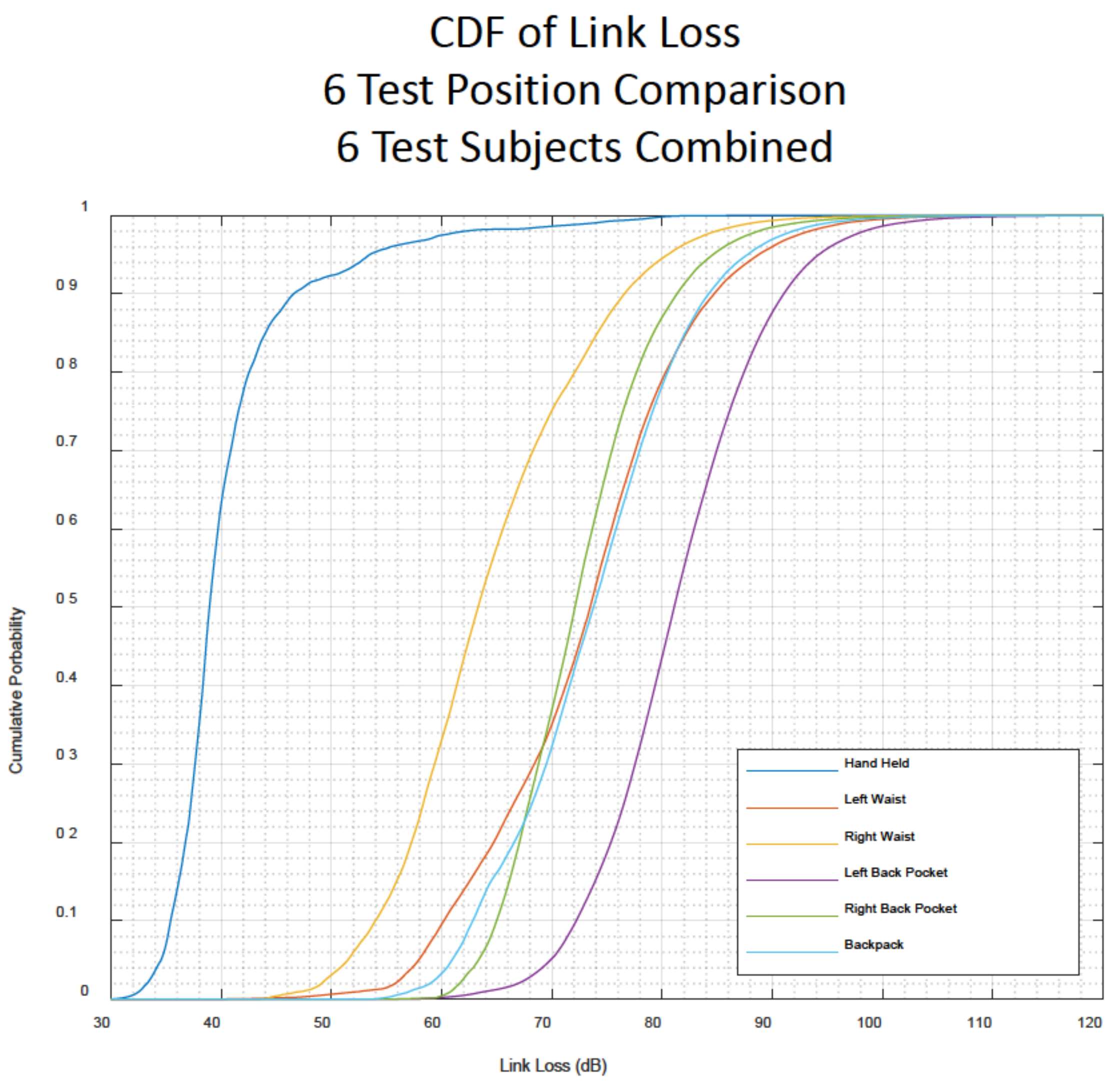
Link Loss CDF, 6 Test Subjects, 6 Positions



Link Loss CDF, BMI Sensitivity

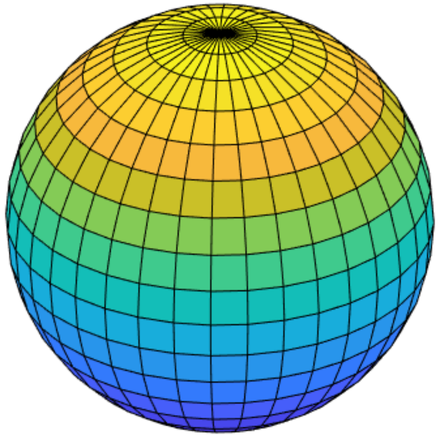


Link Loss CDF, Position Dependency



Normalized Far-Field CDF

- The far-field gain patterns of DUT1 and DUT2 were measured at 3 degree steps in the elevation and the azimuth angles over the entire sphere
- Within a unit surface area, there are more samples of gain patterns near the poles, compared to the equator
- To compute the CDF without a bias in the locations near the poles, the CDF must be normalized by cos(elevation angle) where the elevation angle goes from -90 degrees at the south pole to +90 degrees at the north pole
- All CDF plots in this deck have been normalized to remove polar bias



Summary of Far-field Measurement Methodology

- WRC executes antenna pattern measurements according to IEEE Standard 149 "*IEEE Standard Test Procedures for Antennas*"
  - https://ieeexplore.ieee.org/document/19510

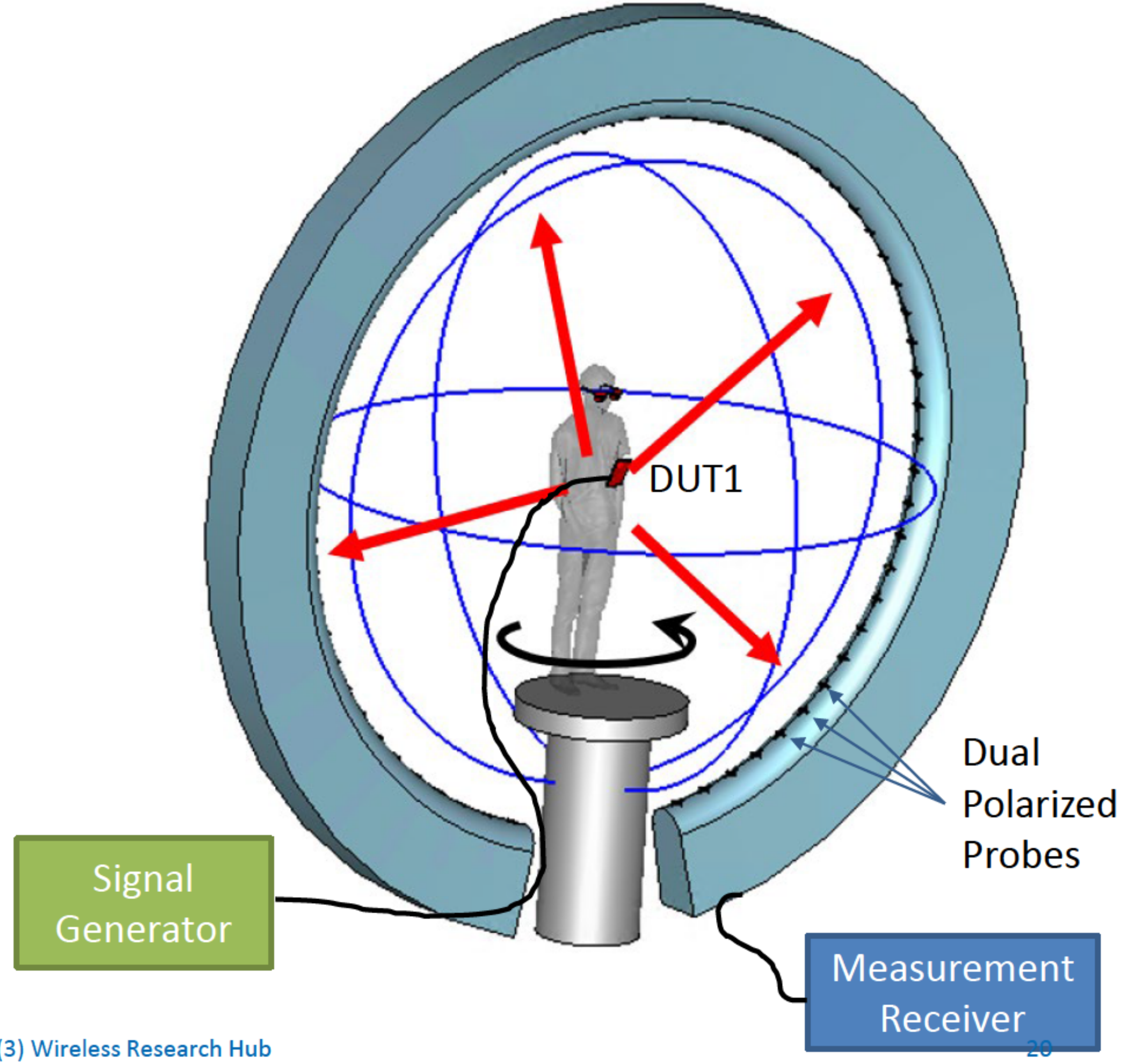
- WRC's Satimo SG-64 uses Spherical Near-Field method to measure antenna pattern
  - Method described in IEEE 149, Section 7.3
  - Measure Amplitude and Phase of radiated signals
  - Two orthogonal polarizations (V-pol and H-pol)
  - Mathematically transform the near-field to far-field

Antenna Radiation Pattern

- Antenna pattern is an angular dependent electromagnetic field radiated from a transmitting antenna
- Antenna pattern changes gradually with the distance
  - Far-Field is the antenna pattern at the infinite distance away from the antenna
  - At some distance R, antenna pattern becomes stable, and does not change significantly from the antenna pattern at infinite distance. This is called far-field zone
  - A rule of thumb of the near-field and the far-field zone distance R
    - Near-Field Zone: $R < \frac{2D^2}{\lambda}$
    - Far-Field Zone: $R \gg \frac{2D^2}{\lambda}$
  - D is size of antenna. For a device on human body, part of the body becomes antenna, and D should include the size of the part of human body
  - λ is the electrical wavelength of the frequency of interest

Near-Field Measurements using SG-64

- 63 probes are equally positioned and embedded in the arch
  - One of 63 probes is selected electronically using RF switches
- Each probe is dual polarized (V-pol and H-pol)
  - Polarization is selected electronically using RF switches
- The human subject with DUT1 (Handset) or DUT2 (Glasses) which are cabled to a signal generator is rotated on the turn table to make full spherical near-field measurements



Near-Field to Far-Field Transform

- For a known complex near-field (amplitude and phase) distribution in two orthogonal polarization (v-pol and h-pol) over a sphere of radius R, the far-field distribution can be computed using near-to-far field transform

- The near-field to far-field transform is well documented in
  - Dan Slater, *"Near-Field Antenna Measurements"*, Artech House, 1991
  - J. E. Hansen (Ed.), *"Spherical Near-Field Antenna Measurements"*, Peter Peregrinus Ltd., 1988

- Near-field method is used in many antenna test chambers in the world

Gain Measurements

- WRC uses Gain-Transfer Method to determine gain of measured antenna pattern as described in IEEE Std 149, Section 12.3

- Gain-Transfer method utilizes testing of the reference antennas with known gain using the same test setup as the DUT testing. The measured patterns of the DUT and the reference antennas with known gain are compared to determine the gain of DUT

- WRC maintains multiple reference antennas that are calibrated according to ISO17025 standards. Their results are traceable to NIST references

Gain Measurement Example

- The DUT antenna is excited by a signal generator with transmit power P_{tx} using coaxial cable with unknown loss L_{coax1} and unknown power amplifier gain G_{PA}
- The radiated signals are received by the probe antenna with unknown gain G_{probe} and fed through coaxial cable with unknown loss L_{coax2} and unknown low noise amplifier gain G_{LNA}, and the received power is recorded by the measurement receiver as P_{rx_DUT} for different directions (θ, φ)
- $P_{rx\_DUT}(\theta, \varphi) = P_{tx} - L_{coax1} + G_{PA} + G_{DUT}(\theta, \varphi) + FSPL + G_{probe} + G_{LNA} - L_{coax2}$
- Similarly, the gain reference antenna measured in the identical environment has measured values of
- $P_{rx\_Reference}(\theta, \varphi) = P_{tx} - L_{coax1} + G_{PA} + G_{Reference}(\theta, \varphi) + FSPL + G_{probe} + G_{LNA} - L_{coax2}$

Gain Measurement Example

- The gain pattern of DUT can be determined from the received power measurements for DUT and the reference antenna, and the gain of the reference antenna using
  - $G_{DUT}(\theta, \varphi) = P_{rx\_DUT}(\theta, \varphi) - P_{rx\_reference}(\theta, \varphi) + G_{Reference}(\theta, \varphi)$

- All other unknowns in the SG-64 measurement system such as signal generator transmit power, coaxial cable losses, amplifier gains, switch losses, are cancelled out

Far-Field vs Link-Loss Tests

- Far-field test measures the radiated field strengths from DUT1 or DUT2 individually in the far distance from the DUT in the presence of human test subjects

- Includes effects of
  - Antenna gain pattern for each DUT in the full sphere (e.g. including DUT antenna pattern mismatch)
  - Body loss and body effects on the gain pattern

- Does not include
  - Polarization mismatch because the radiation patterns were measured using dual polarization probes, and polarization independent gain patterns were calculated, and used in CDF analysis
  - Free Space Path Loss. The antenna gain is calculated for the far-field with large but arbitrary separation distance

- Link Loss-test measures the field strength at output port of antenna in the glasses when the signal was injected to the antenna on the handset which were worn in various positions on the test subject

- Includes the effects of
  - Propagation losses over the given separation distance between DUT1 and DUT2
  - Impact of the human body and body effects on the gain pattern
  - Antenna pattern mismatch losses between DUT1 and DUT2
  - Polarization mismatch loss between DUT1 and DUT2

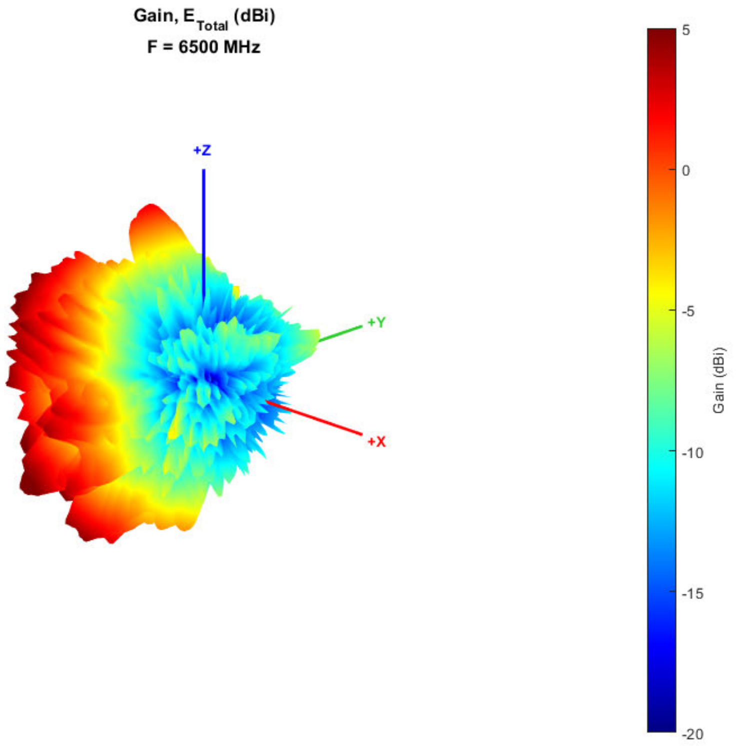
Appendix 2

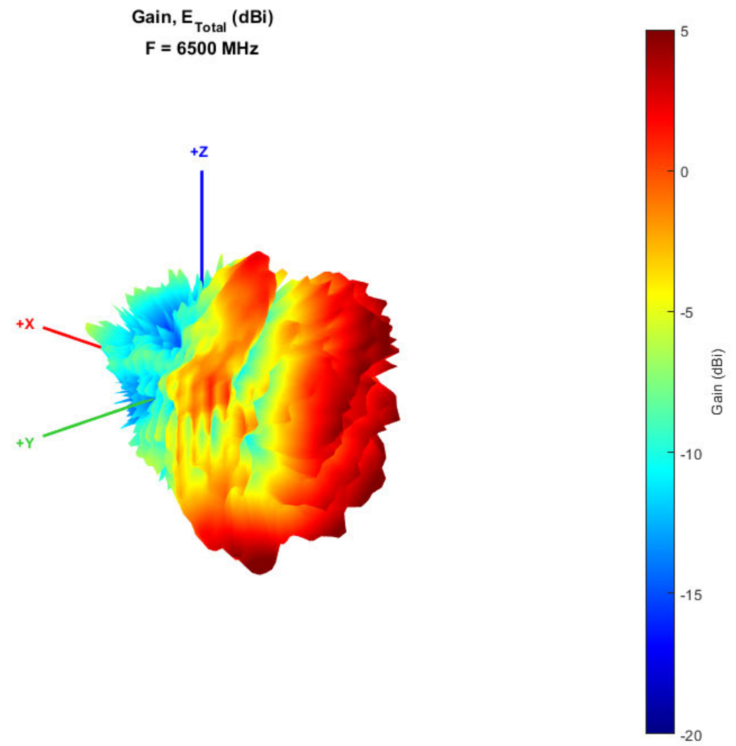
3D Far-Field Pattern Plots

9/23/2020

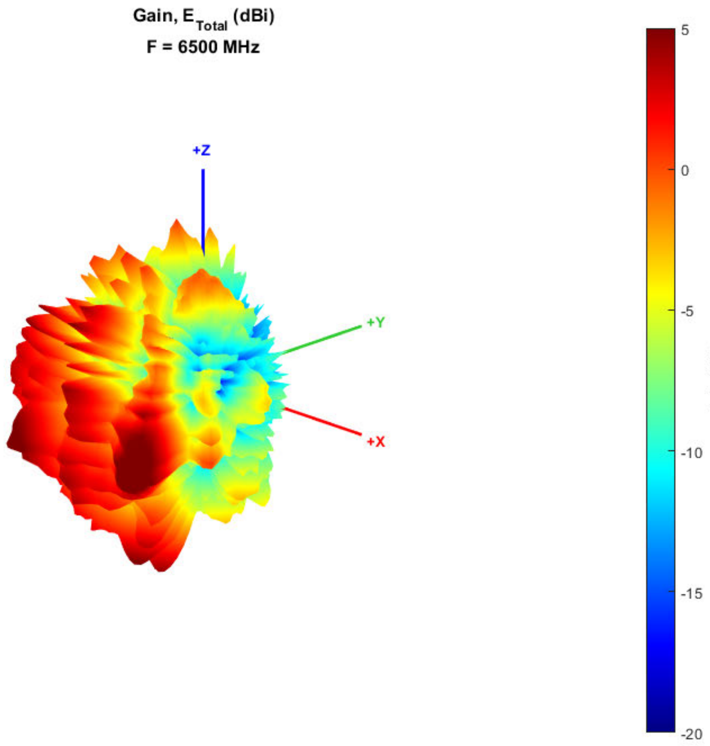
All 6 Test Subjects
Handset for 2 Positions
Glasses for Forward Pointing

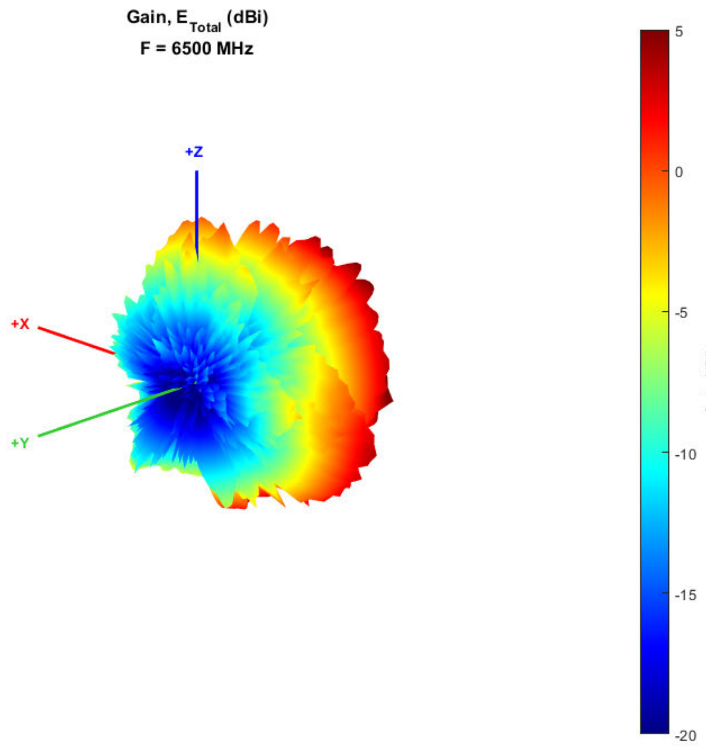
Subject A, Left Back Pocket



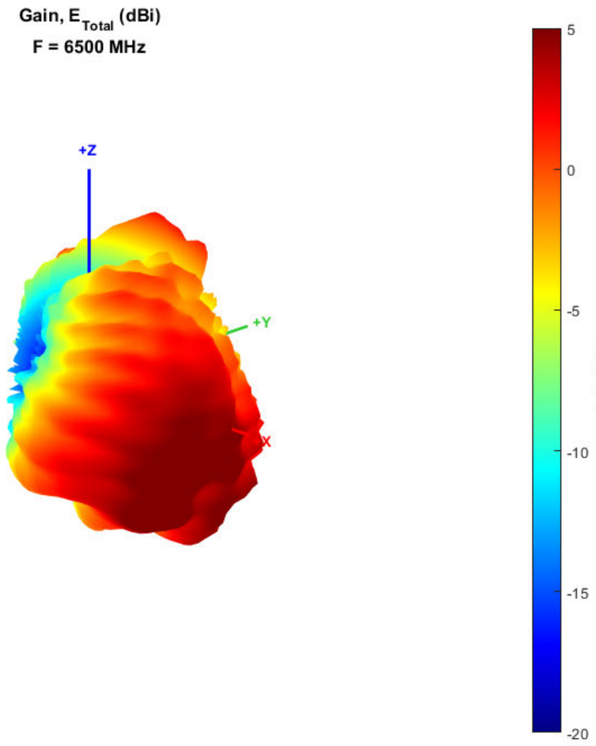


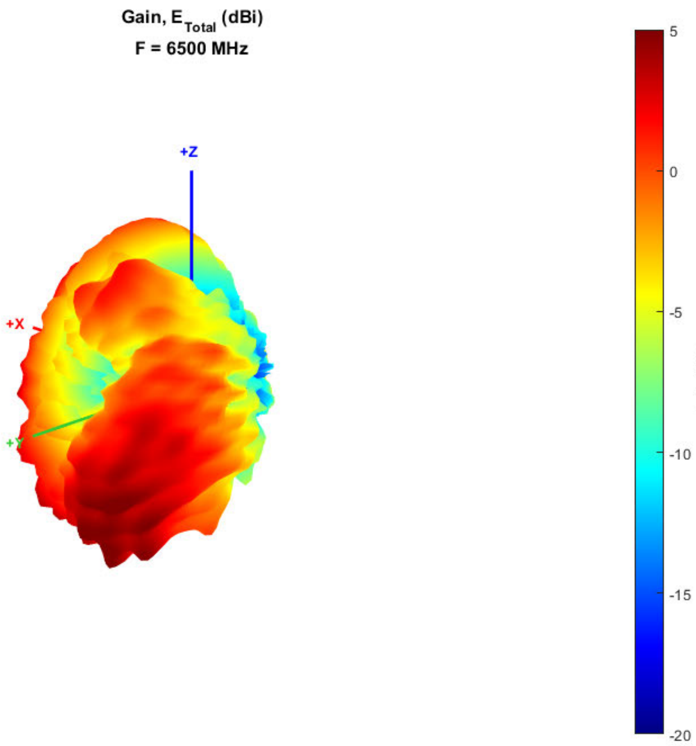
Subject A, Backpack



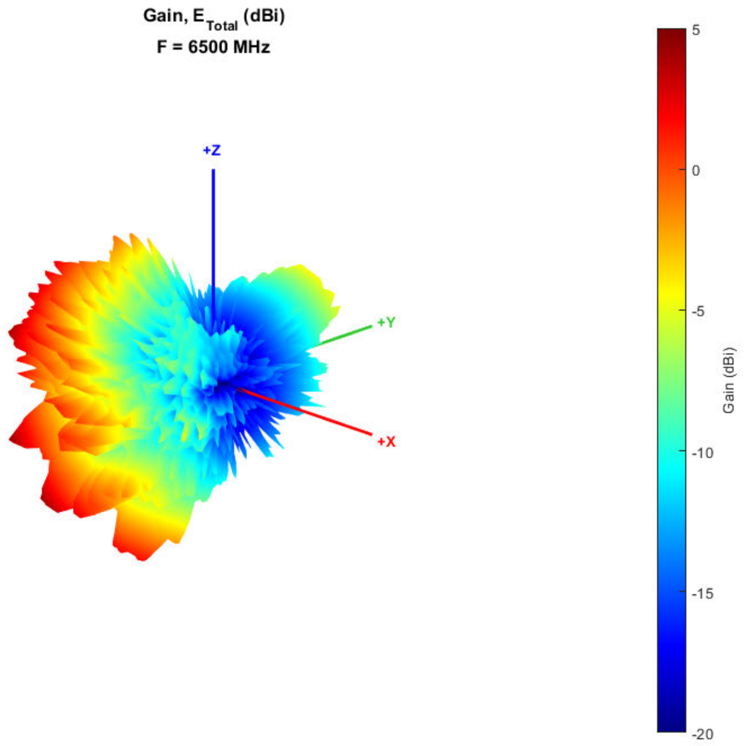


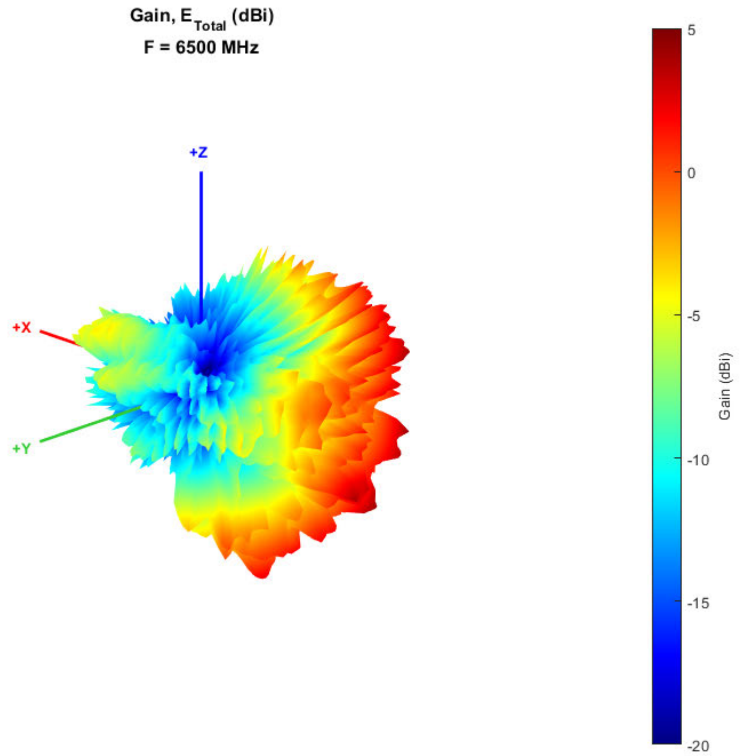
Subject A, Glasses



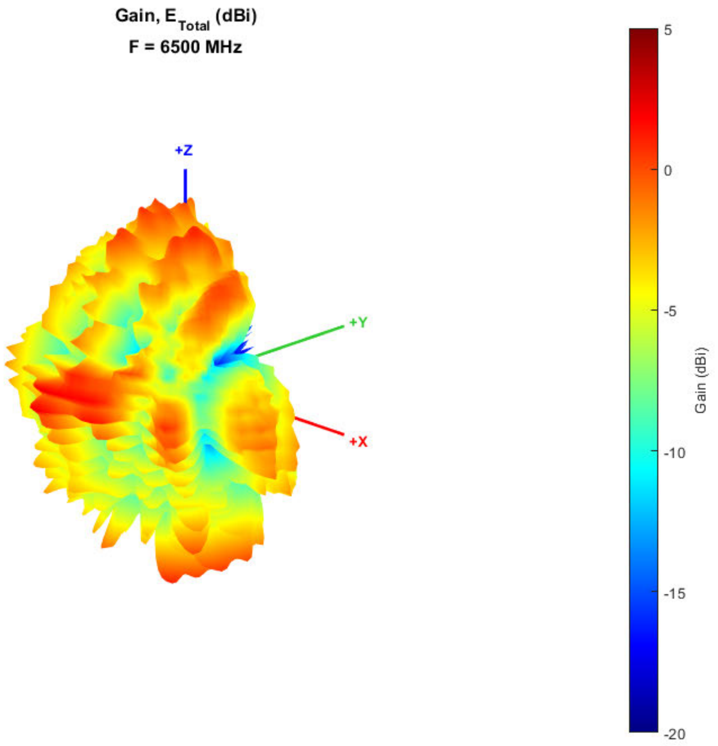


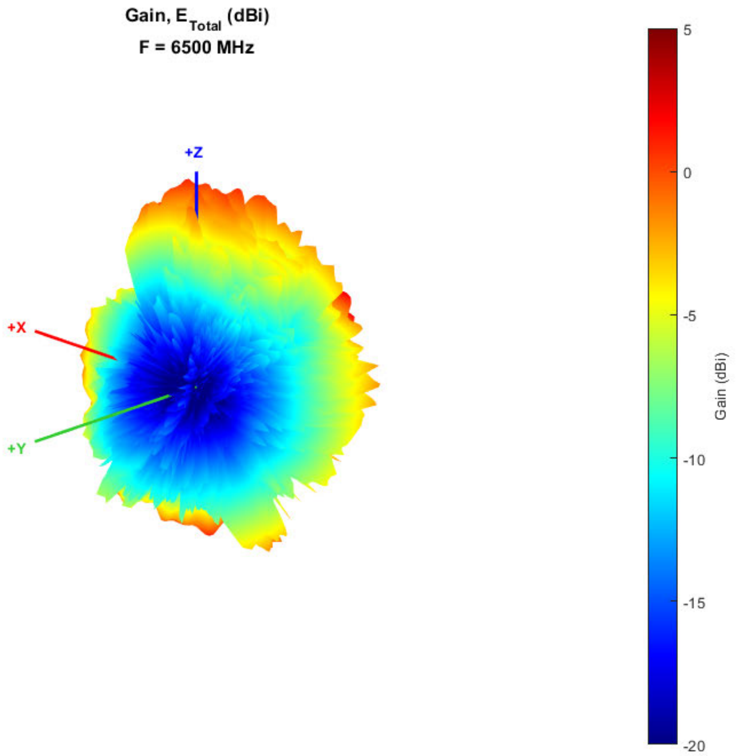
Subject B, Left Back Pocket



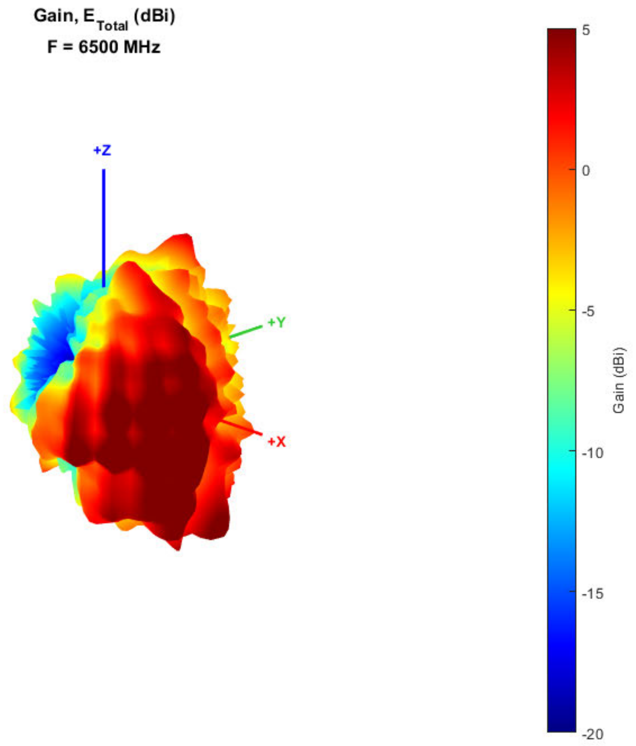


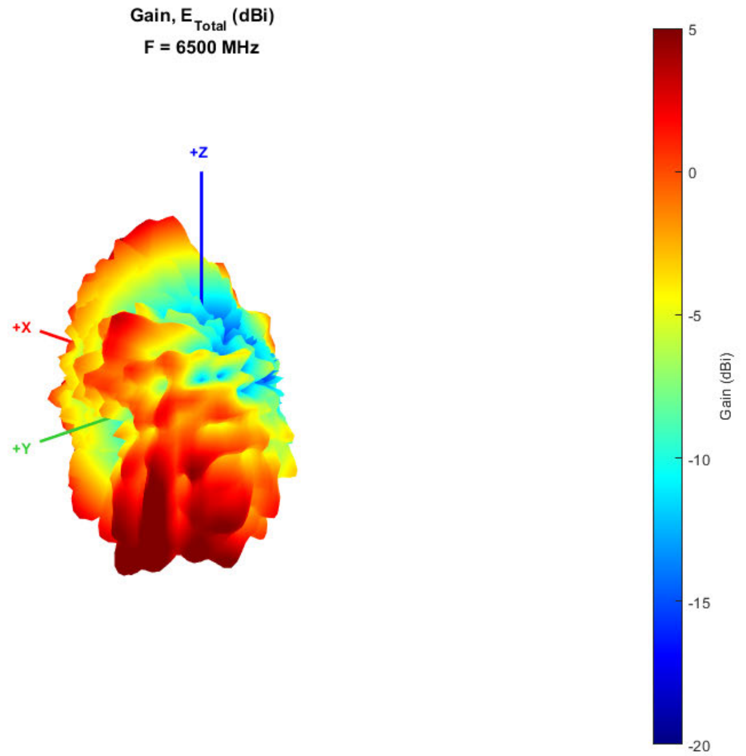
Subject B, Backpack



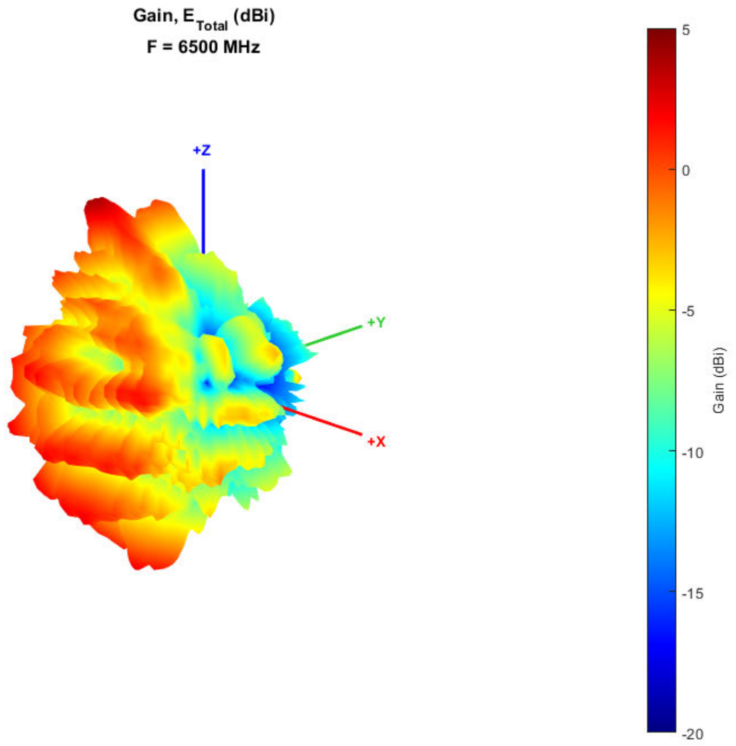


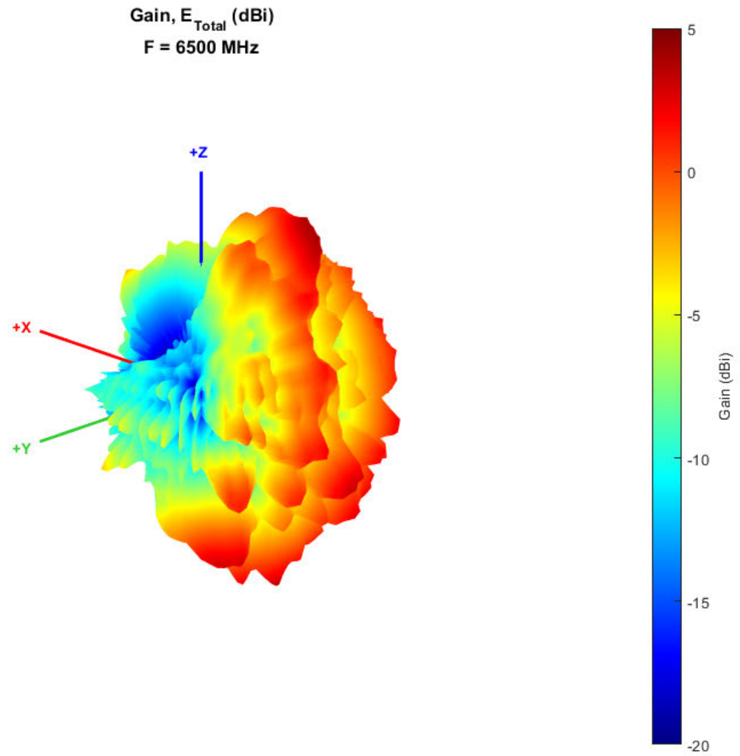
Subject B, Glasses



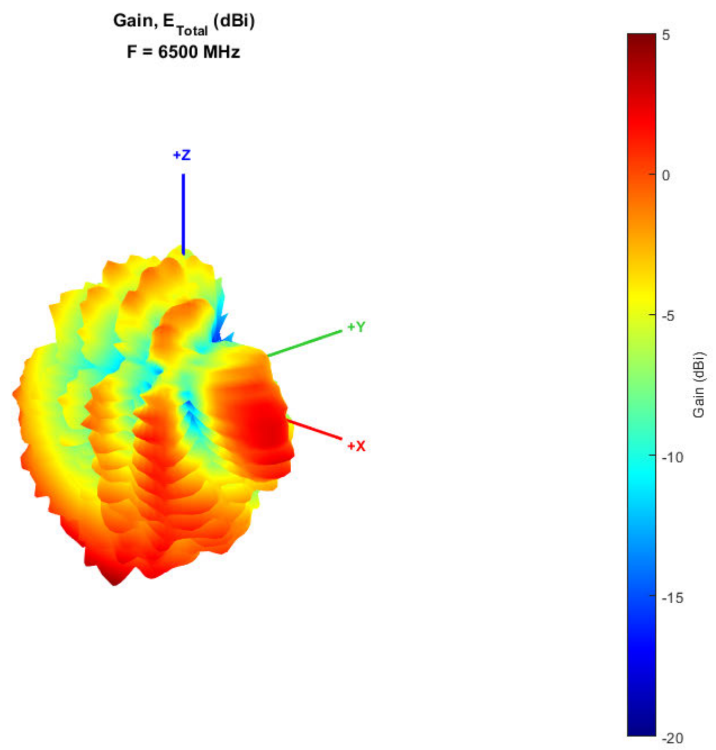


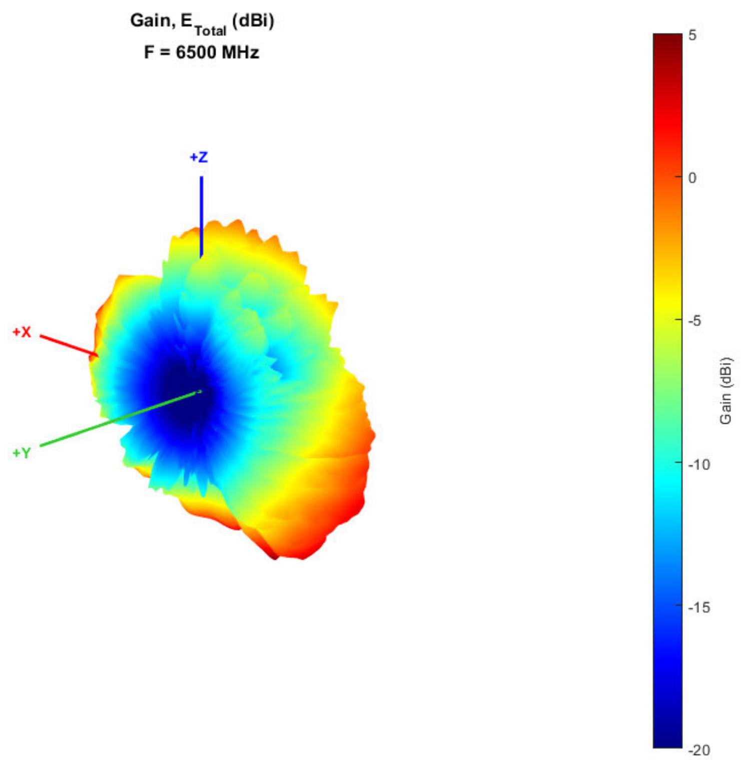
Subject C, Left Back Pocket



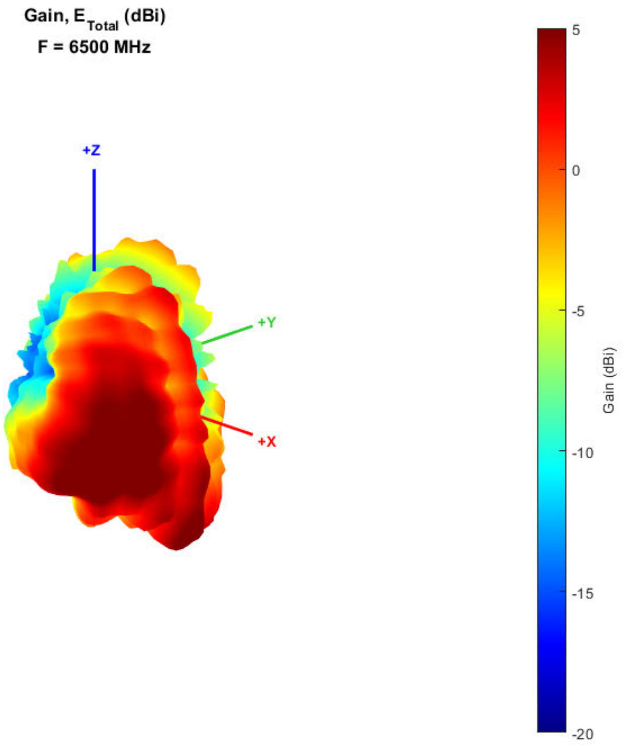


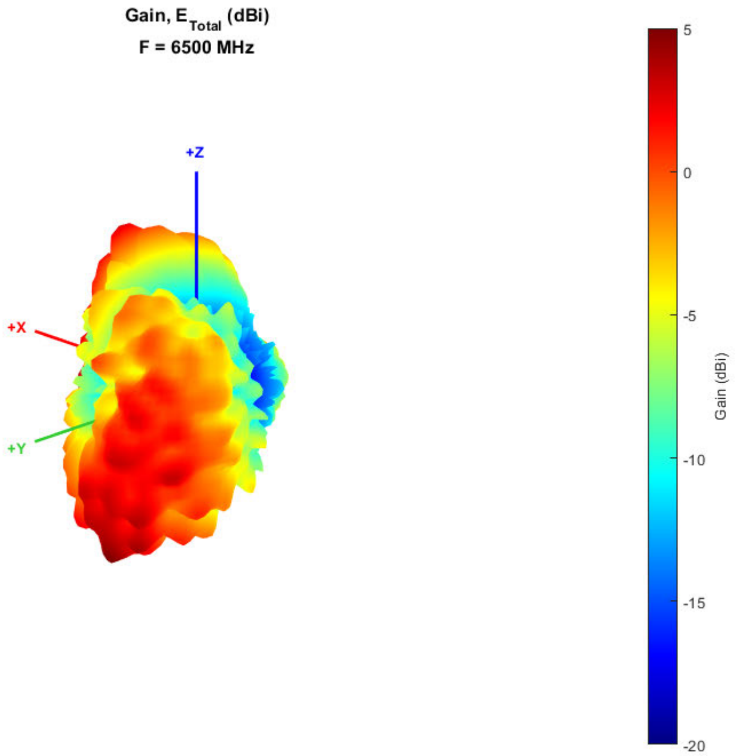
Subject C, Backpack



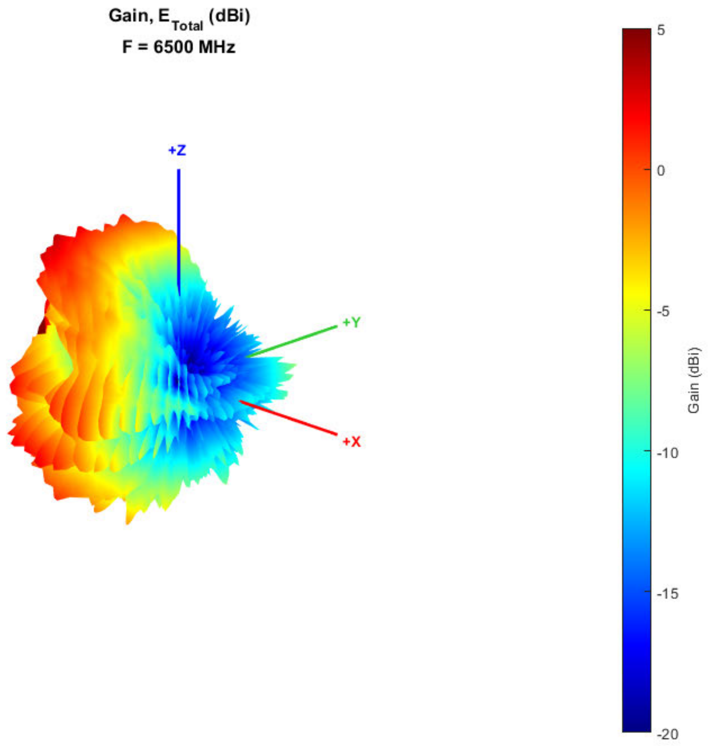


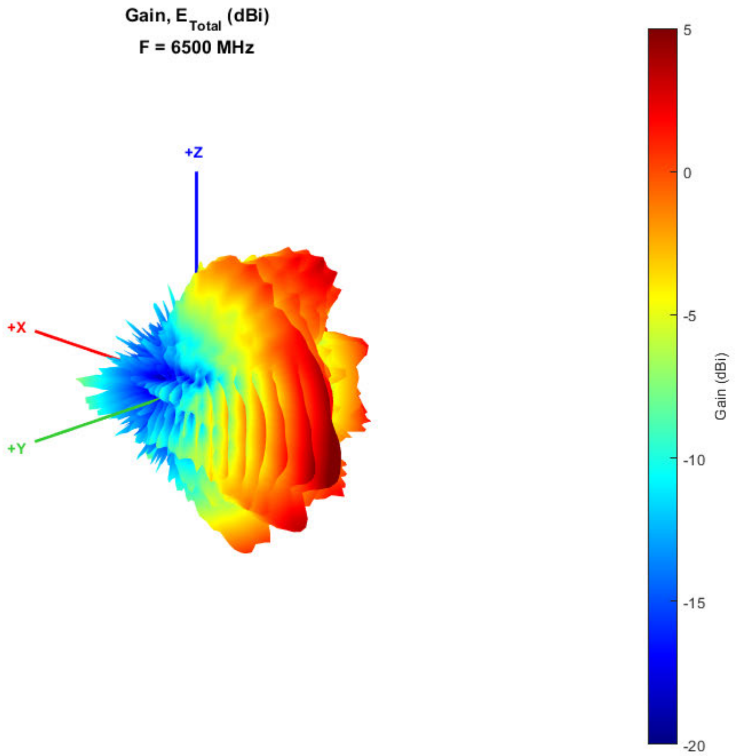
Subject C, Glasses



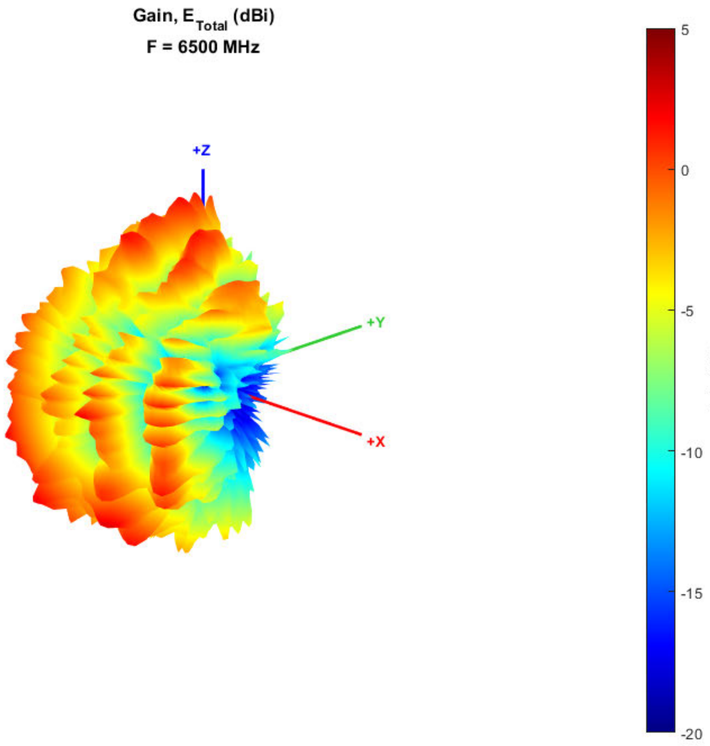


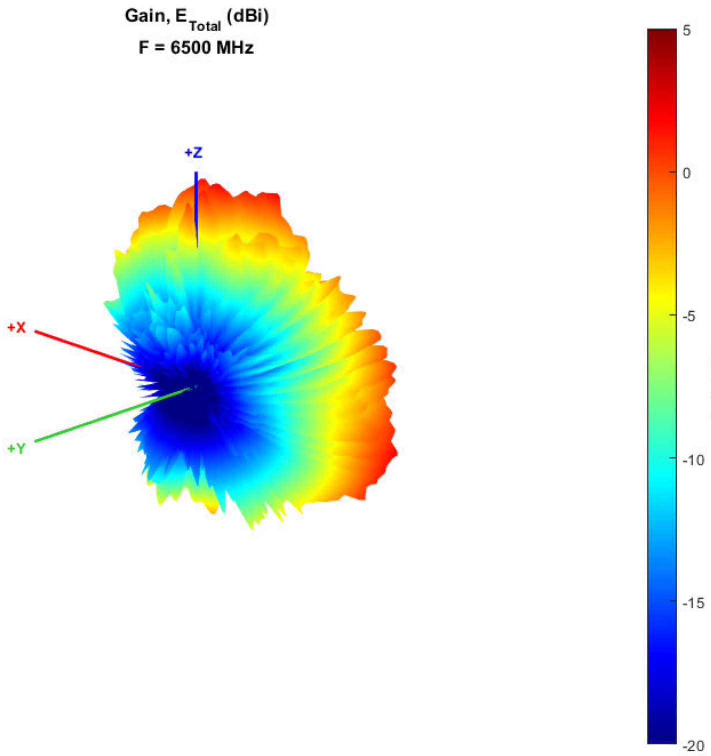
Subject D, Left Back Pocket



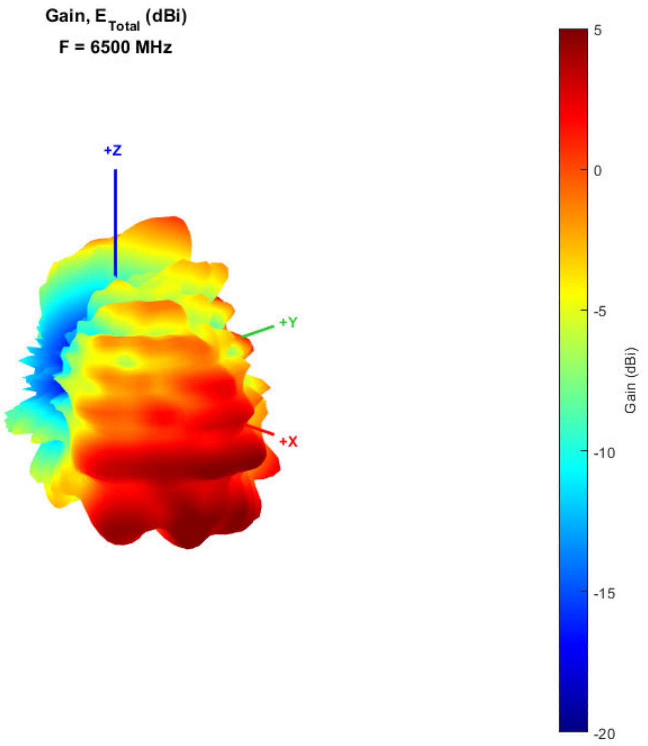


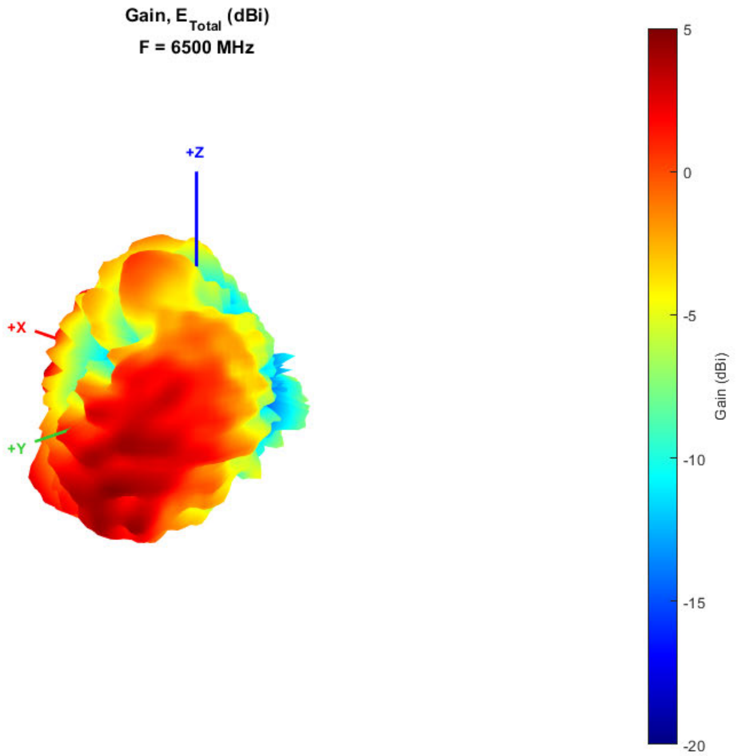
Subject D, Backpack



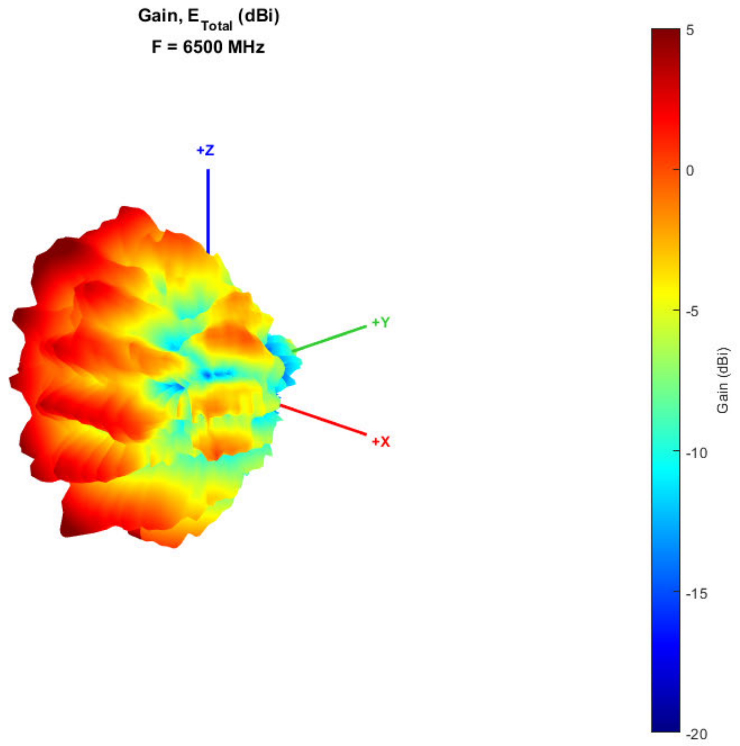


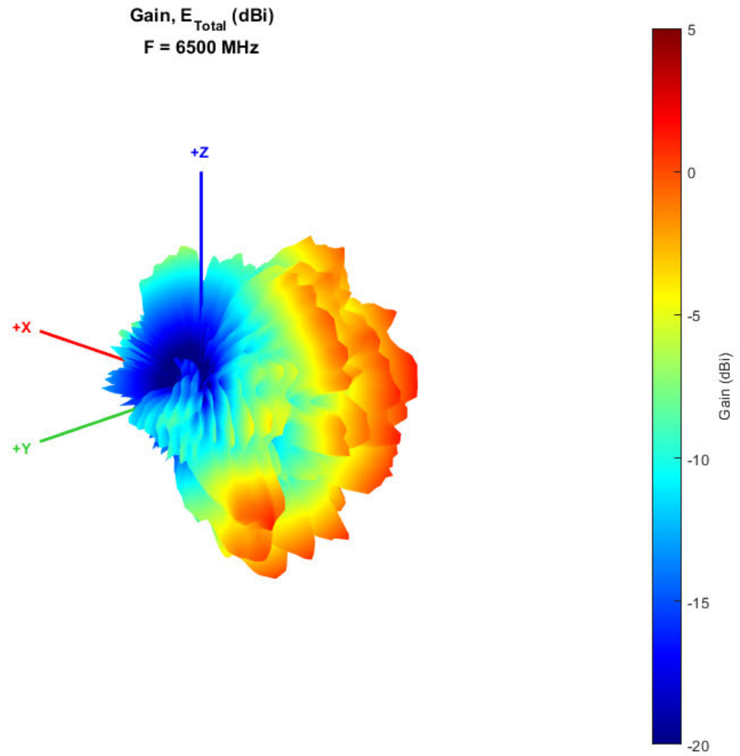
Subject D, Glasses



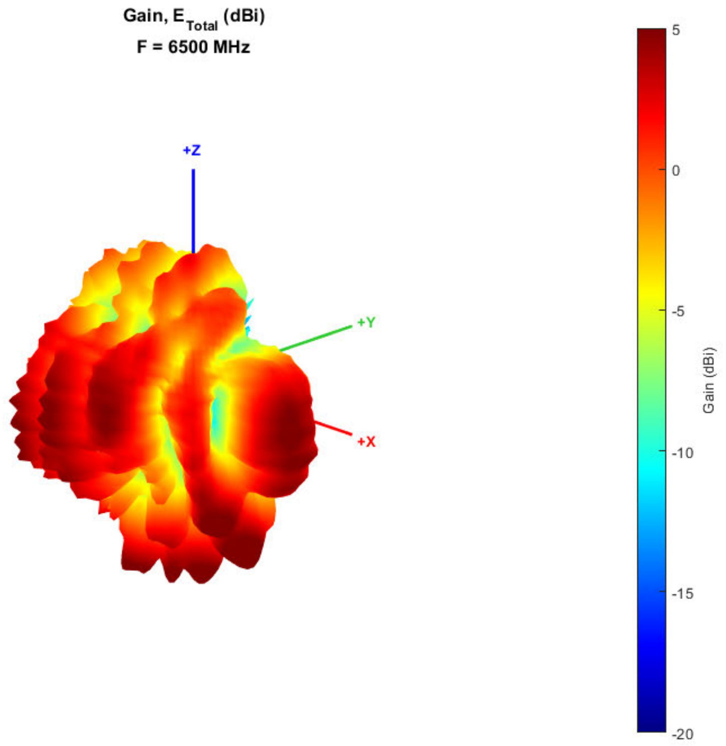


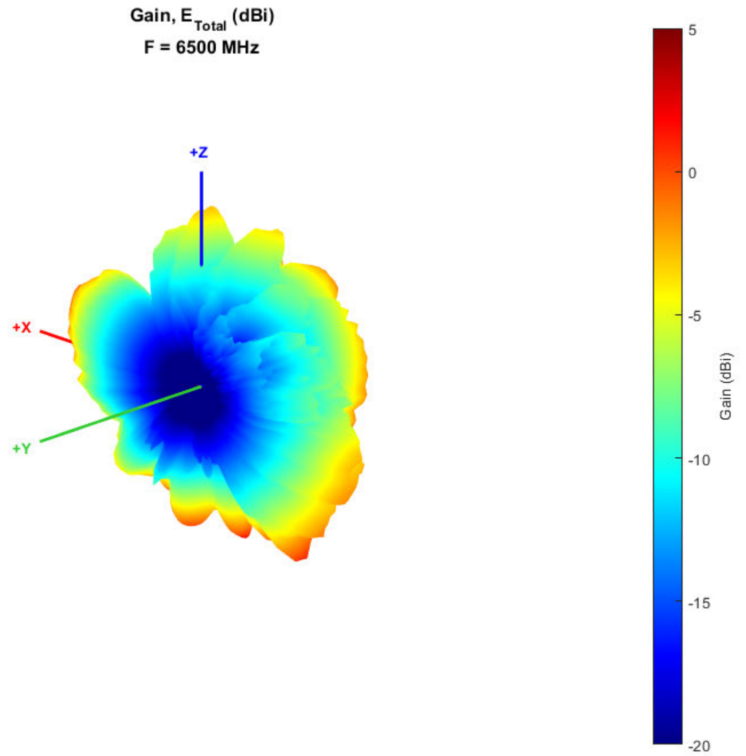
Subject E, Left Back Pocket



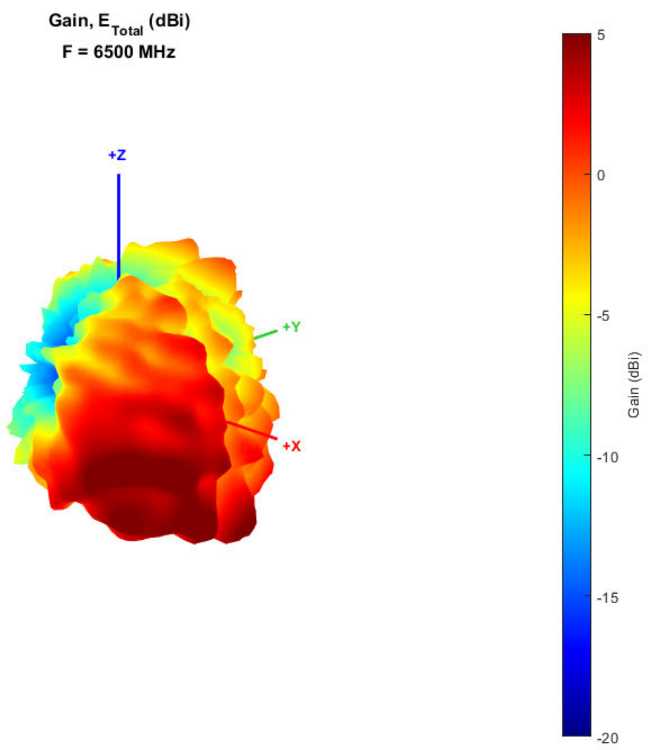


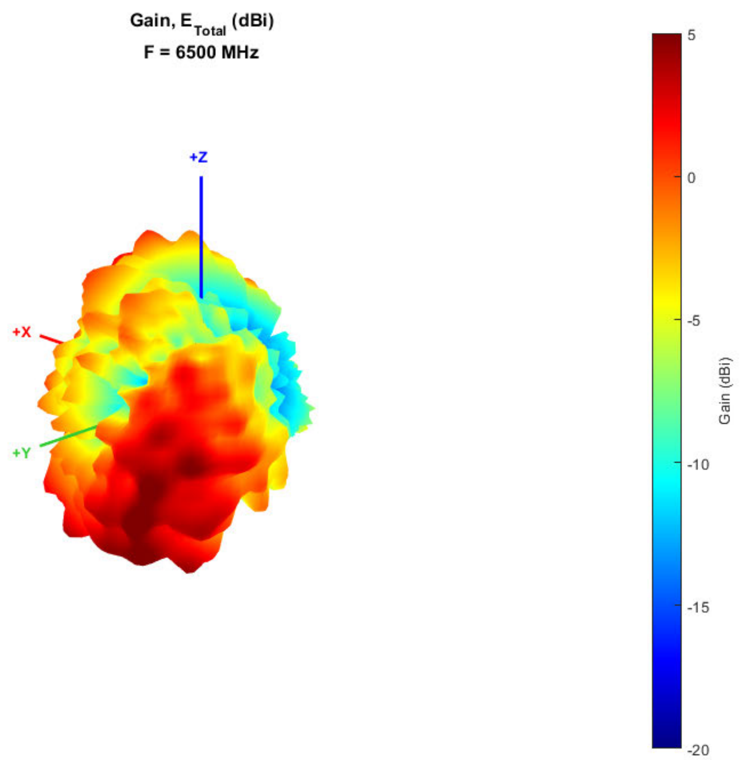
Subject E, Backpack



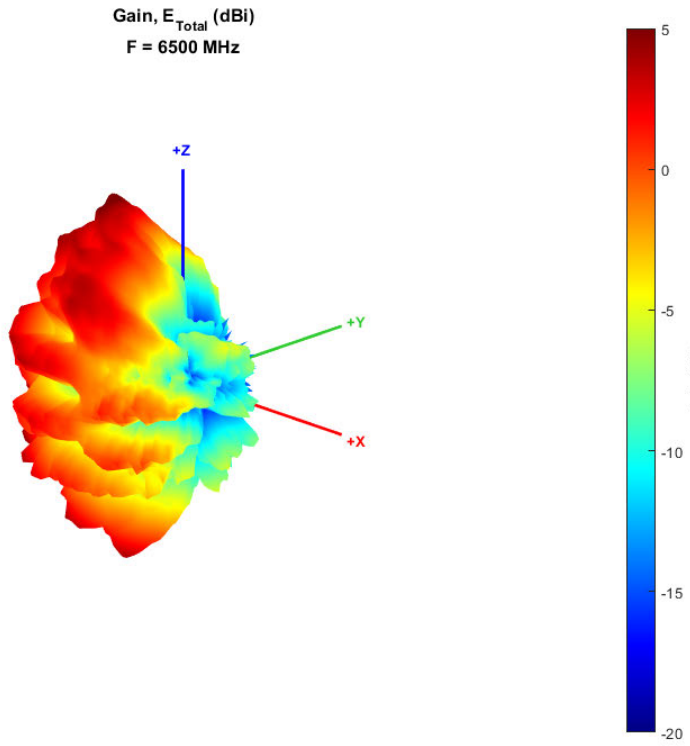


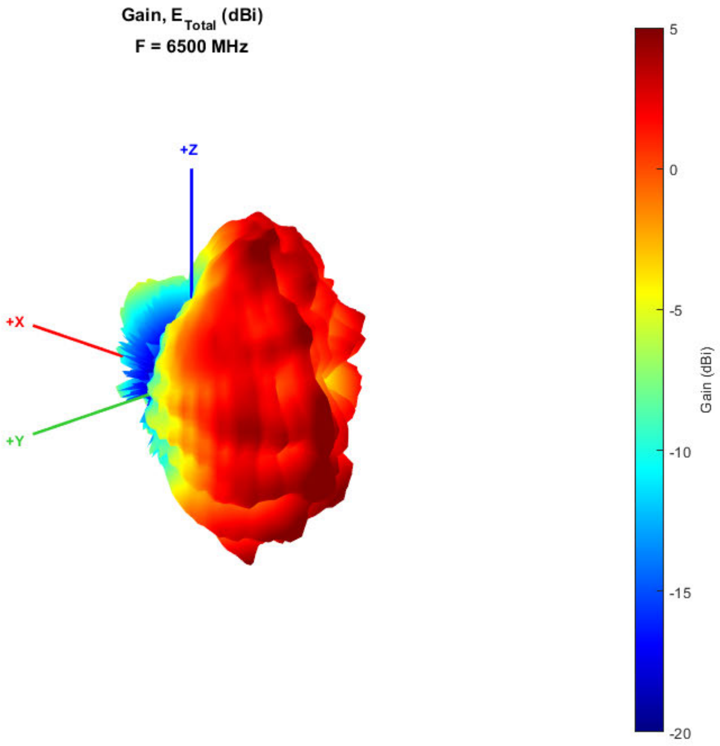
Subject E, Glasses



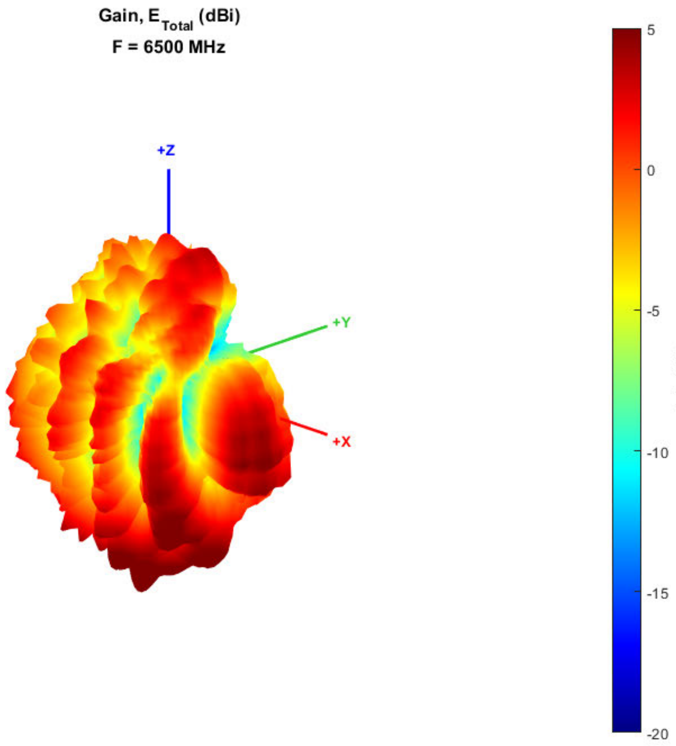


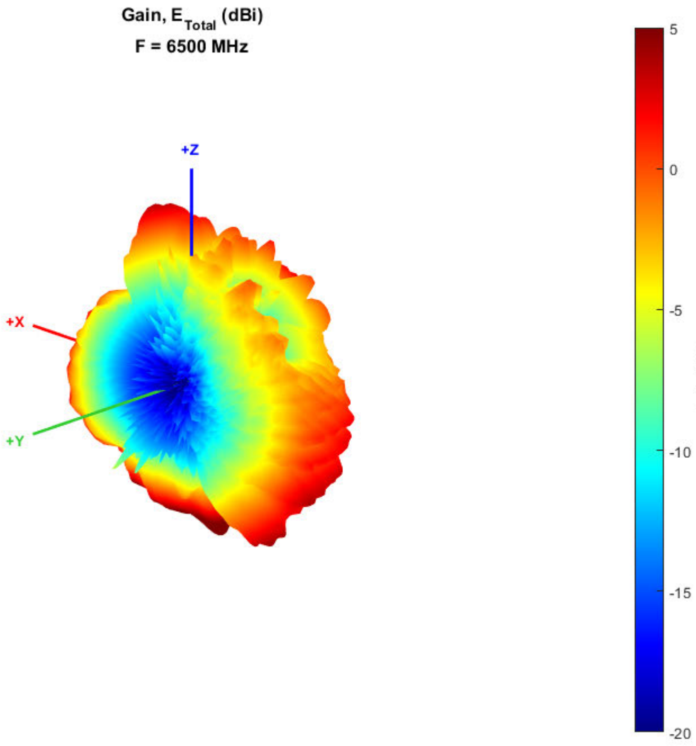
Subject F, Left Back Pocket



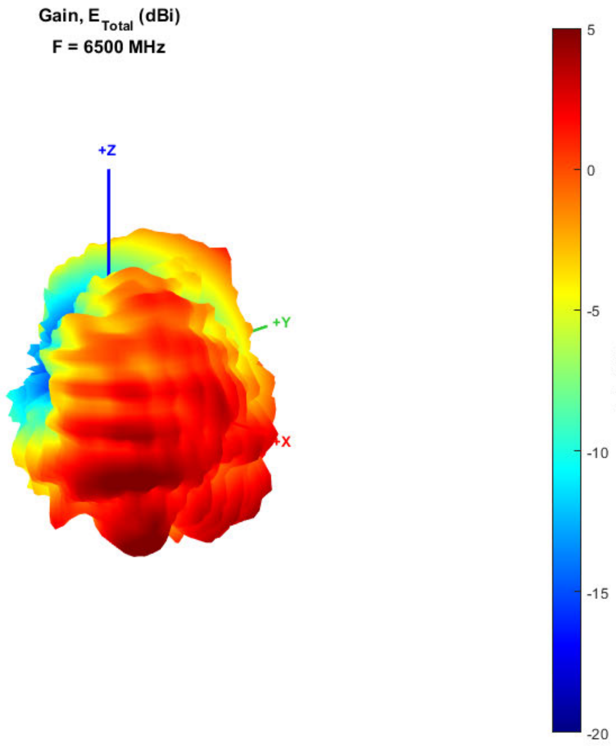


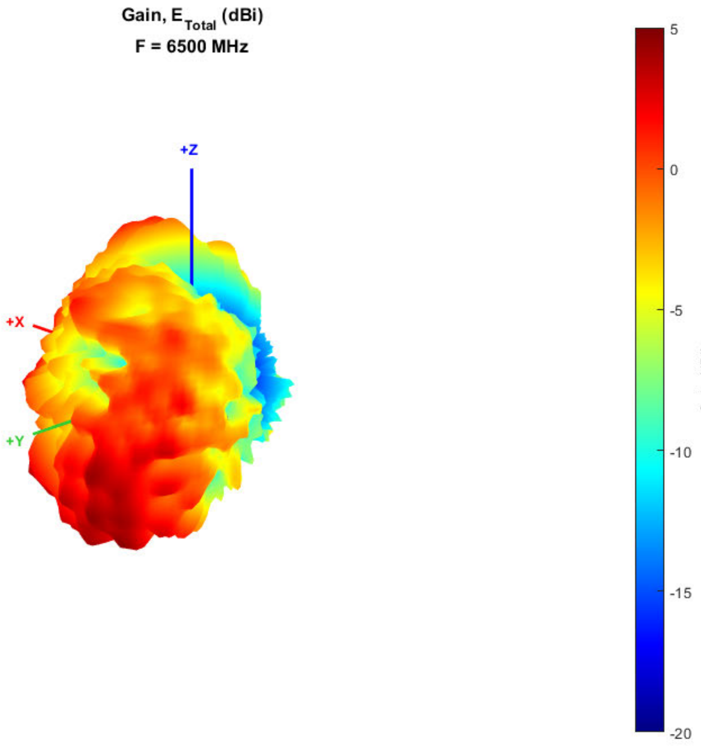
Subject F, Backpack





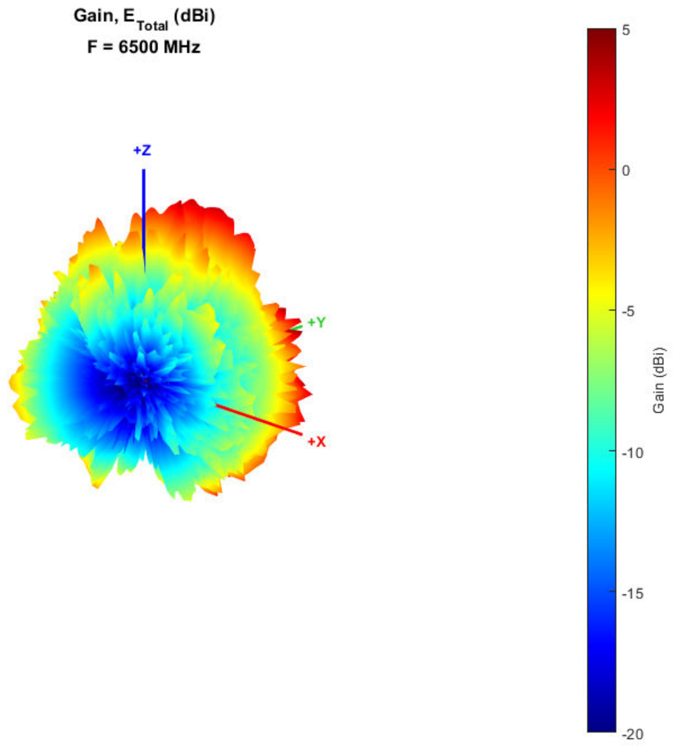
Subject F, Glasses

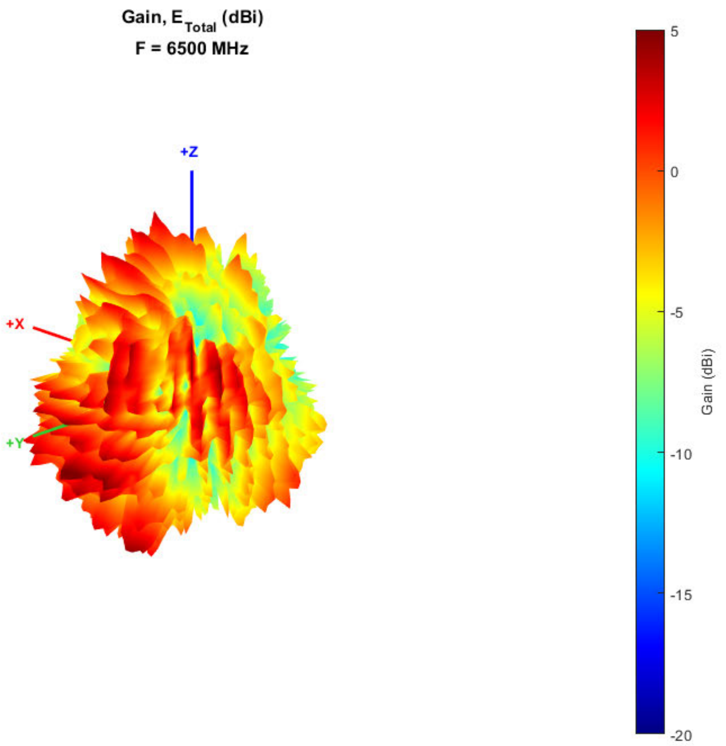




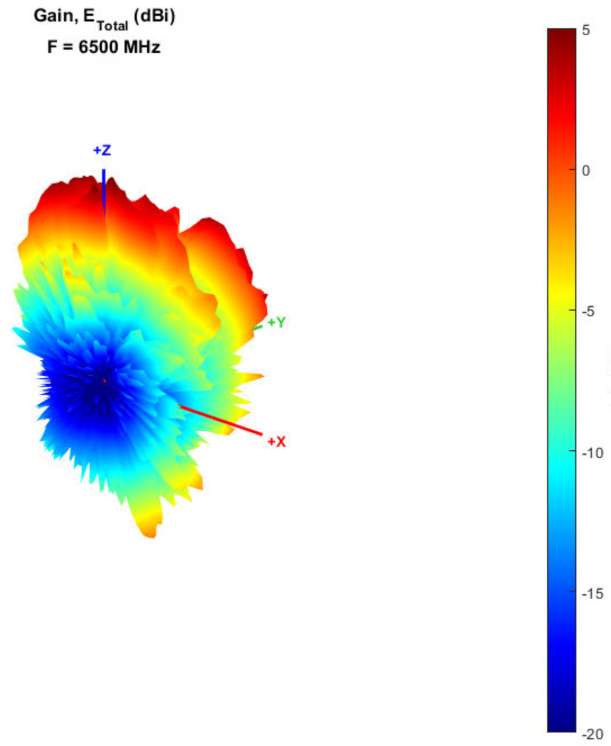
Test Subject A
Handset, 6 Positions & 4 Orientations
Glasses, 3 Head pointing

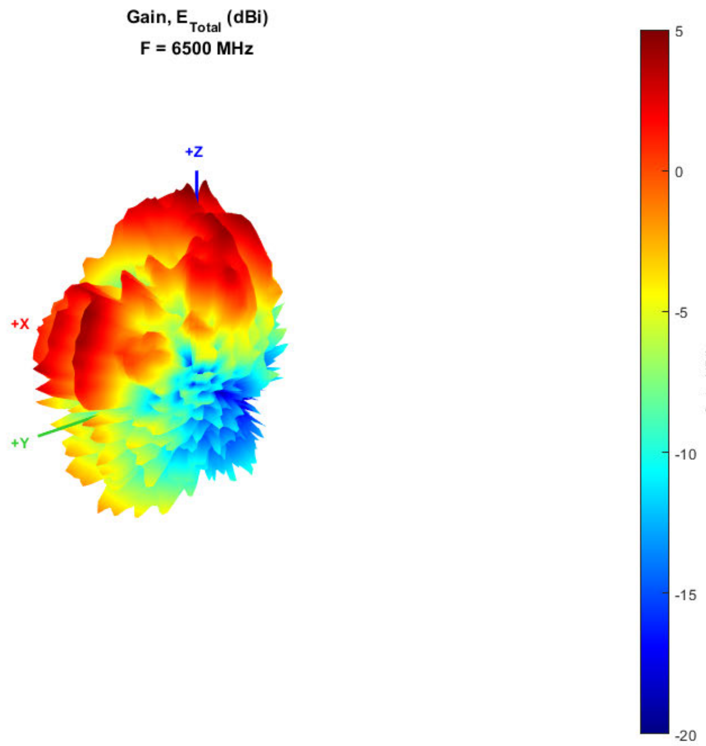
Subject A, Hand Held, Vertical Antenna Top



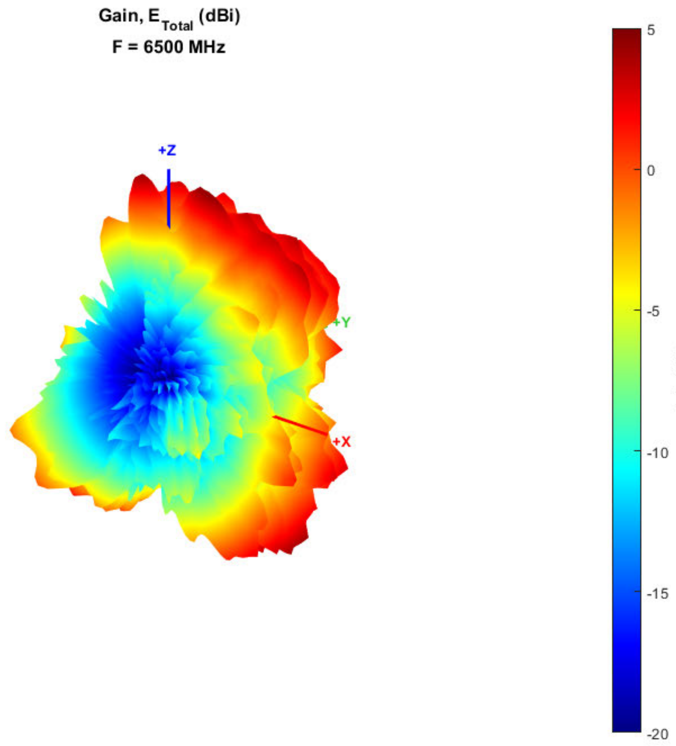


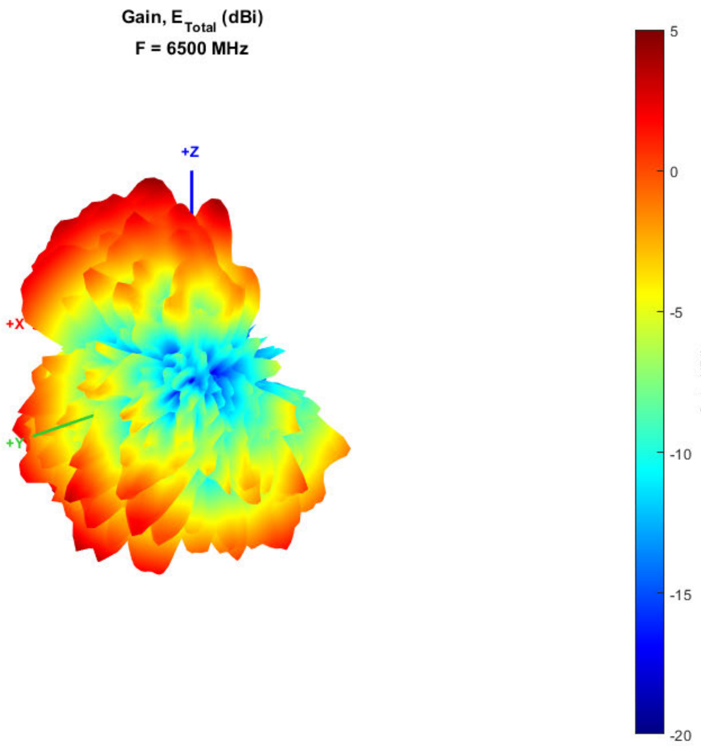
Subject A, Hand Held, Vertical Antenna Bottom



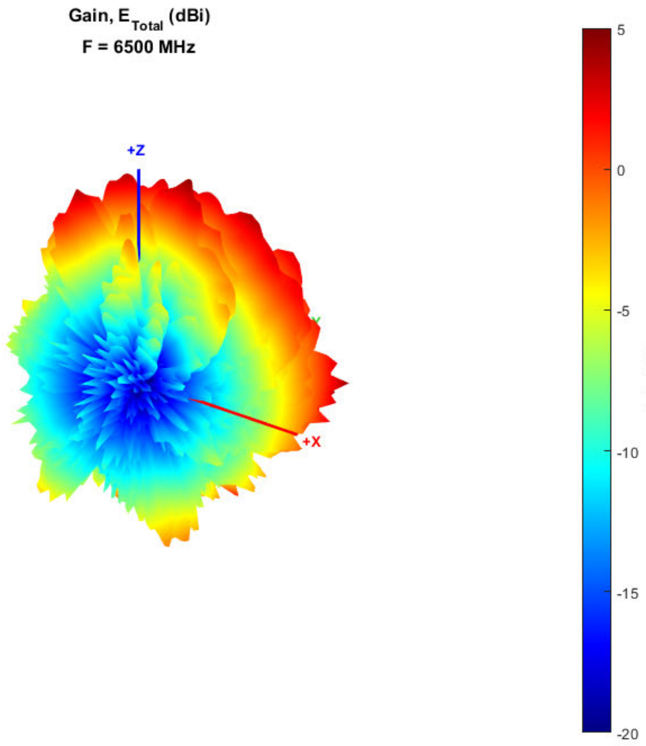


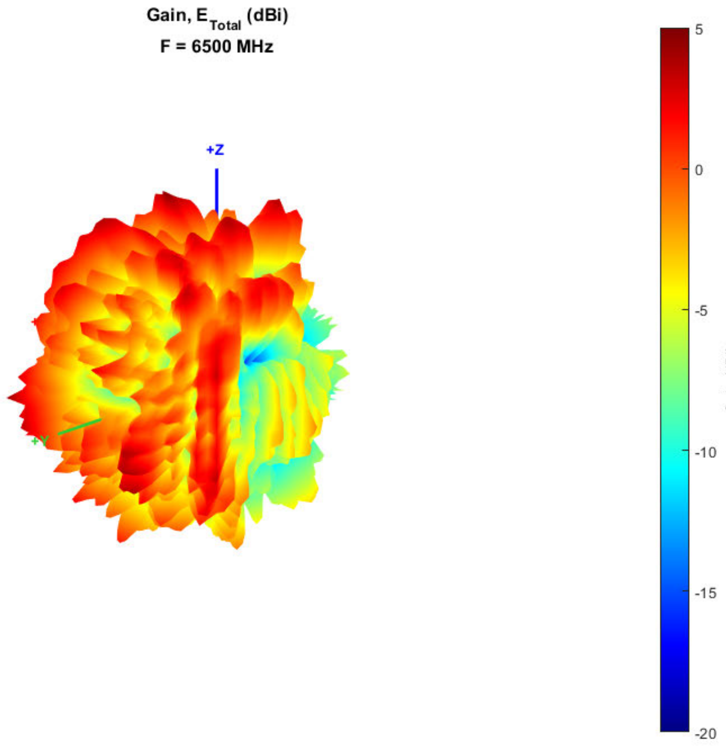
Subject A, Hand Held, Horizontal Antenna Top



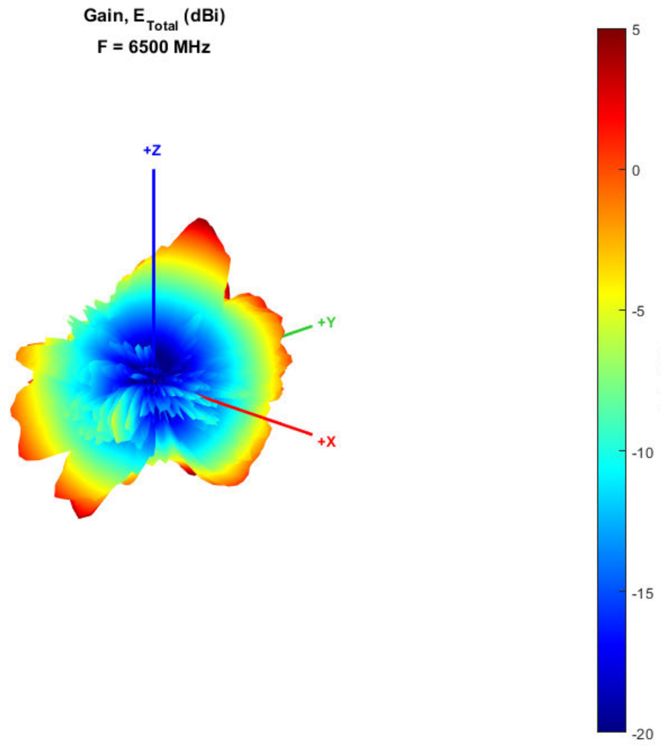


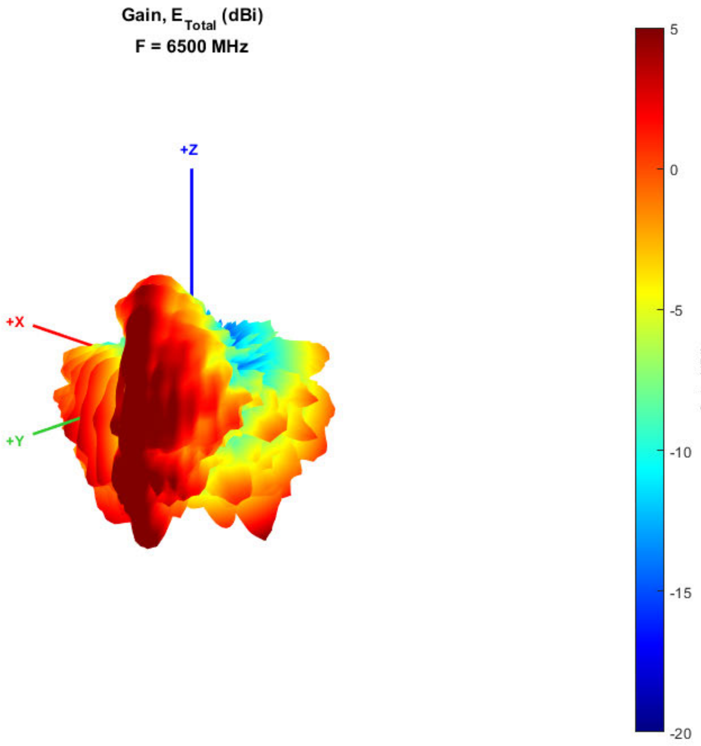
Subject A, Hand Held, Horizontal Antenna Bottom



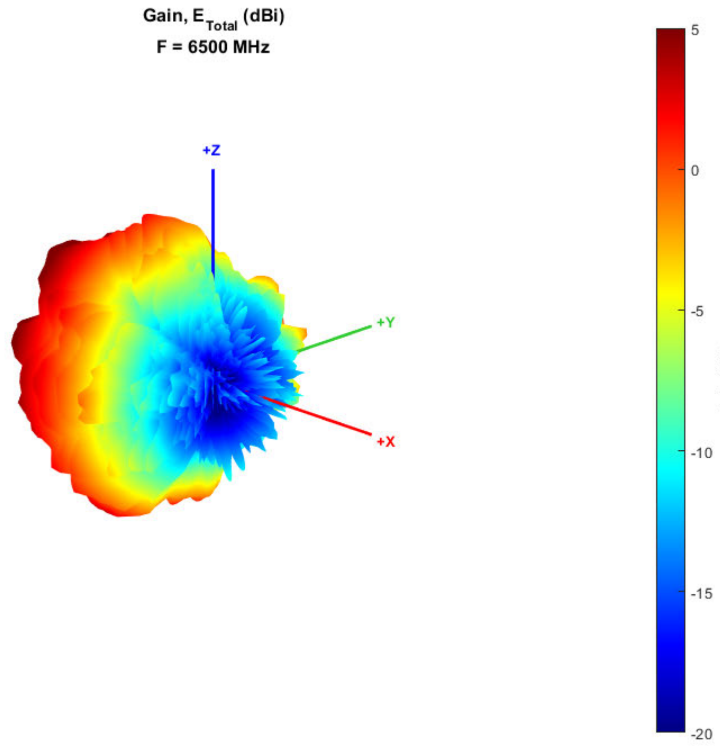


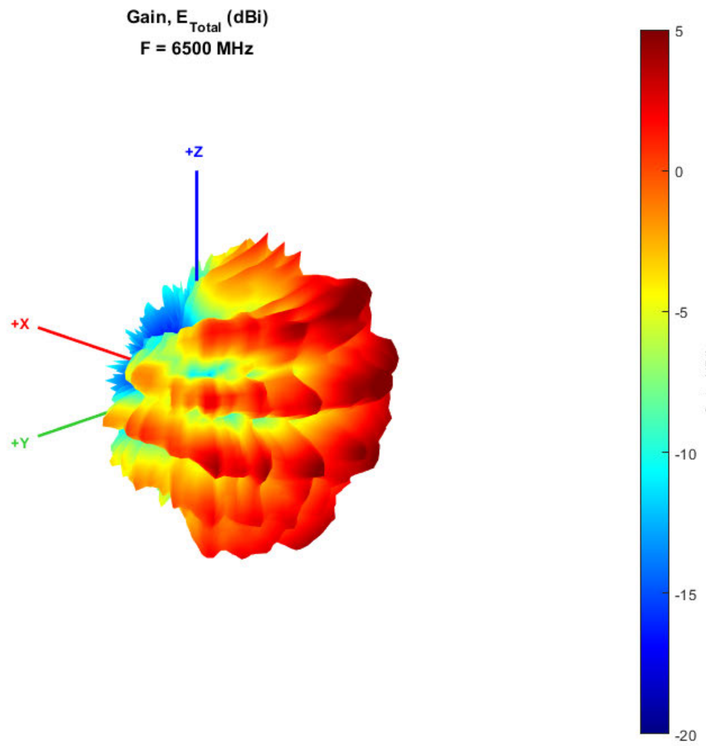
Subject A, Left Waist, Vertical Antenna Top



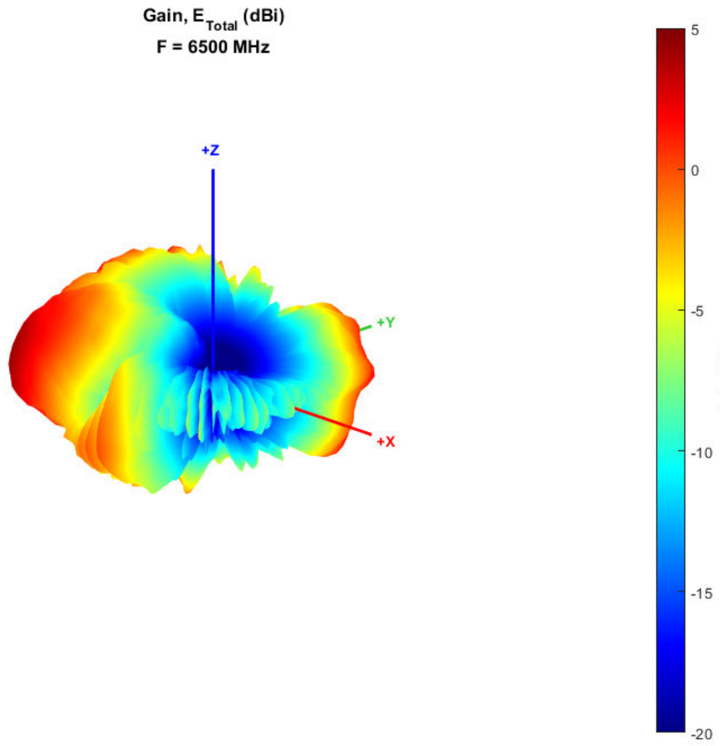


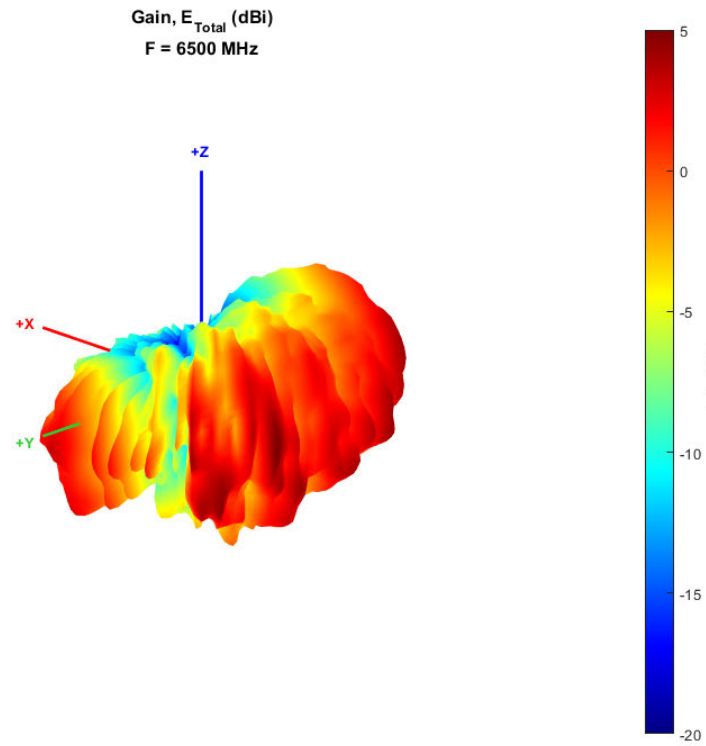
Subject A , Left Waist, Vertical Antenna Bottom



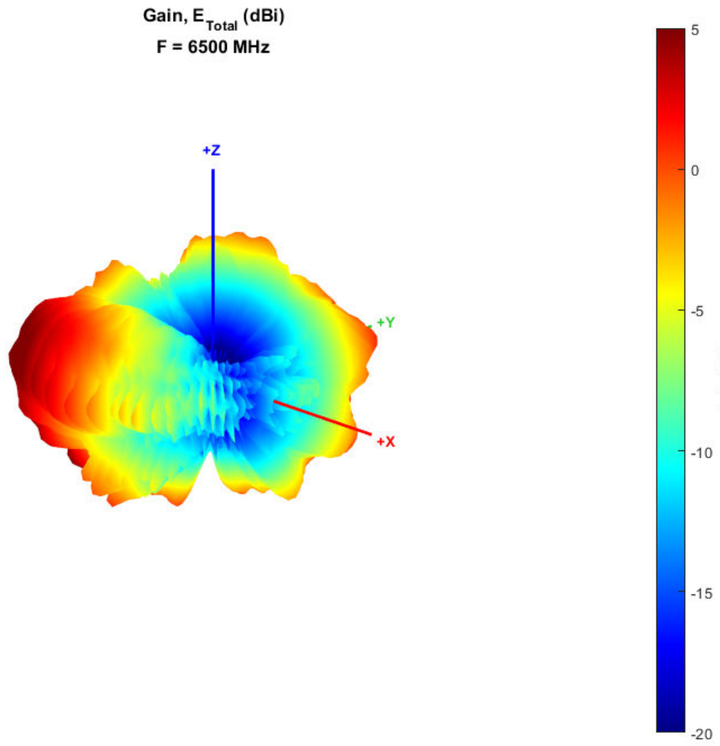


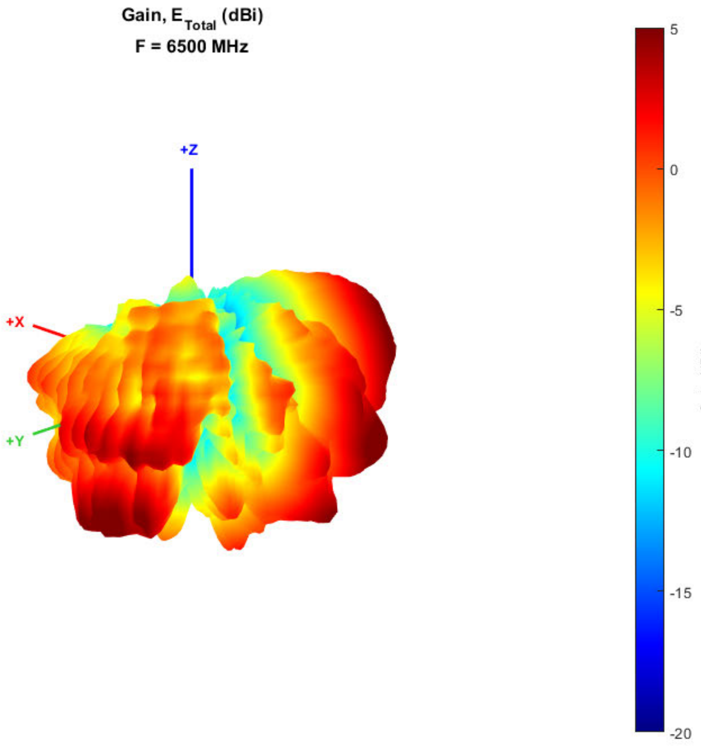
Subject A , Left Waist, Horizontal Antenna Top



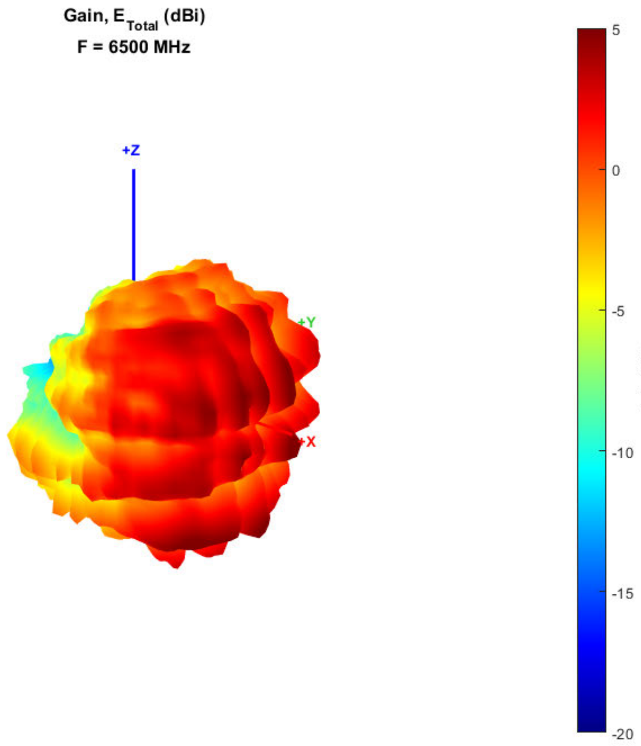


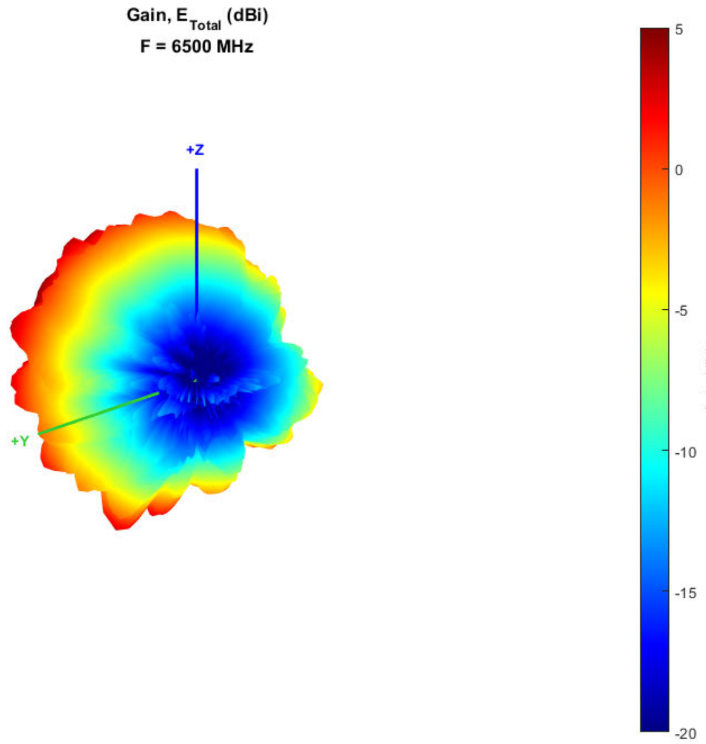
Subject A , Left Waist, Horizontal Antenna Bottom



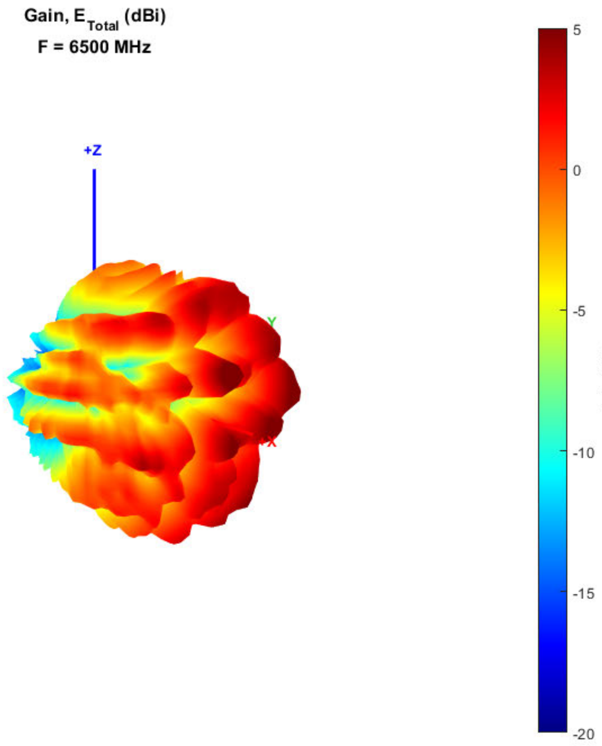


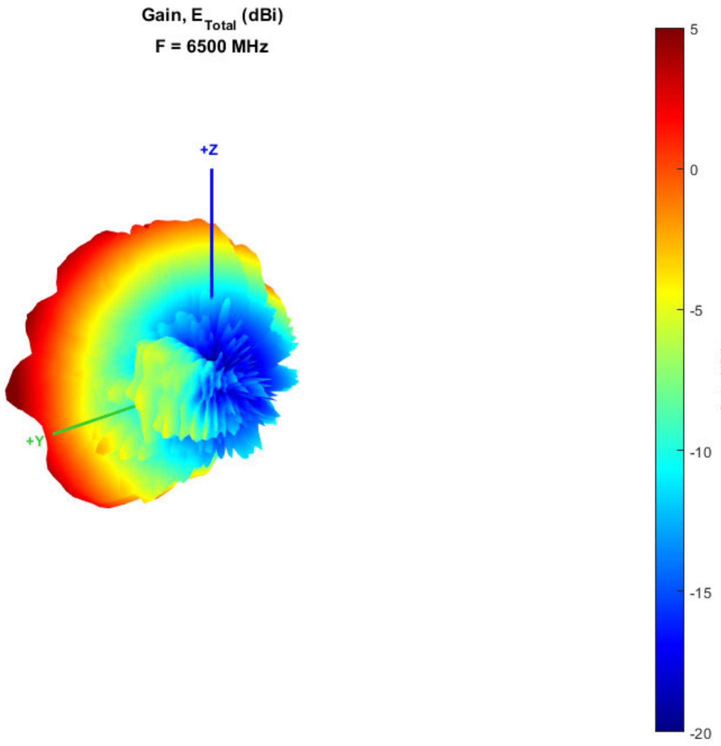
Subject A , Right Waist, Vertical Antenna Top



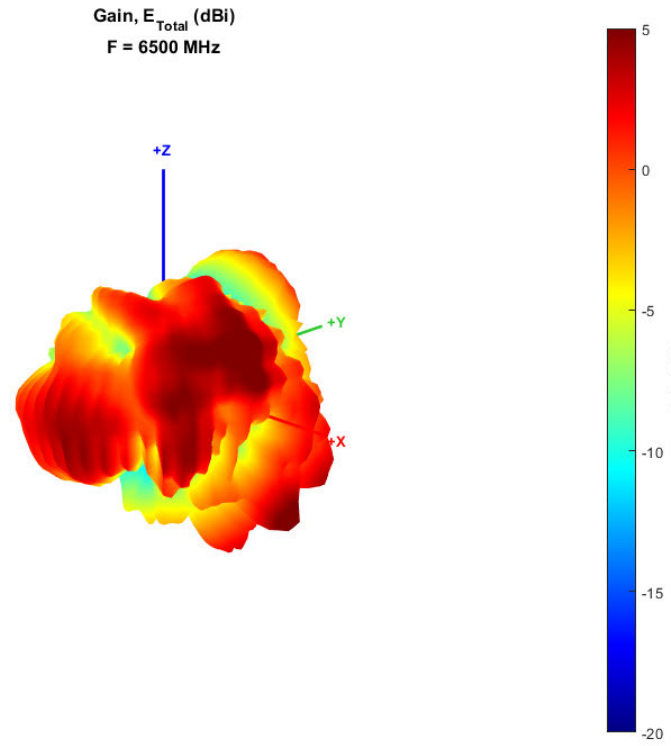


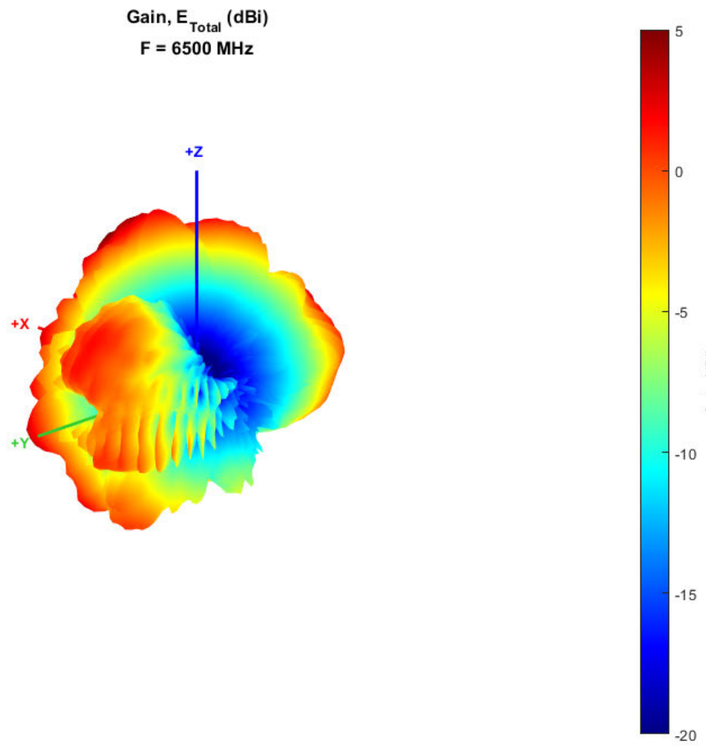
Subject A , Right Waist, Vertical Antenna Bottom



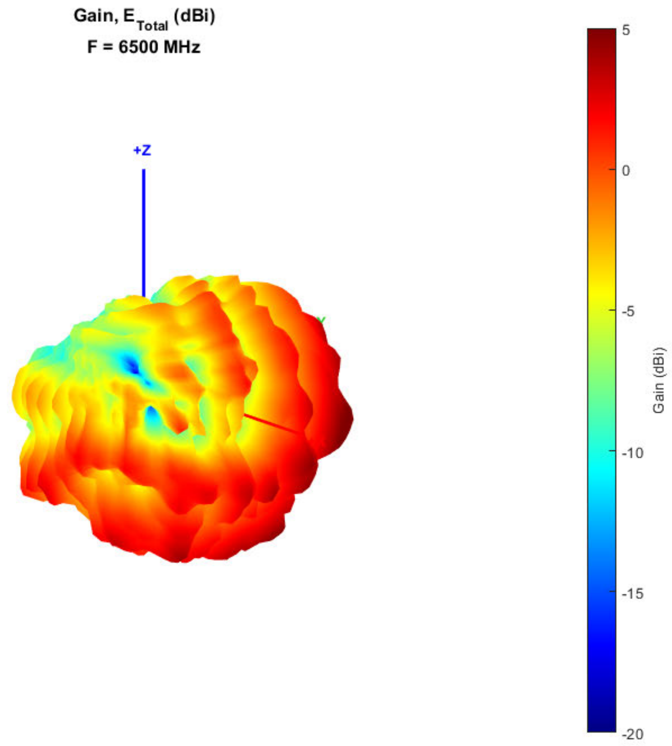


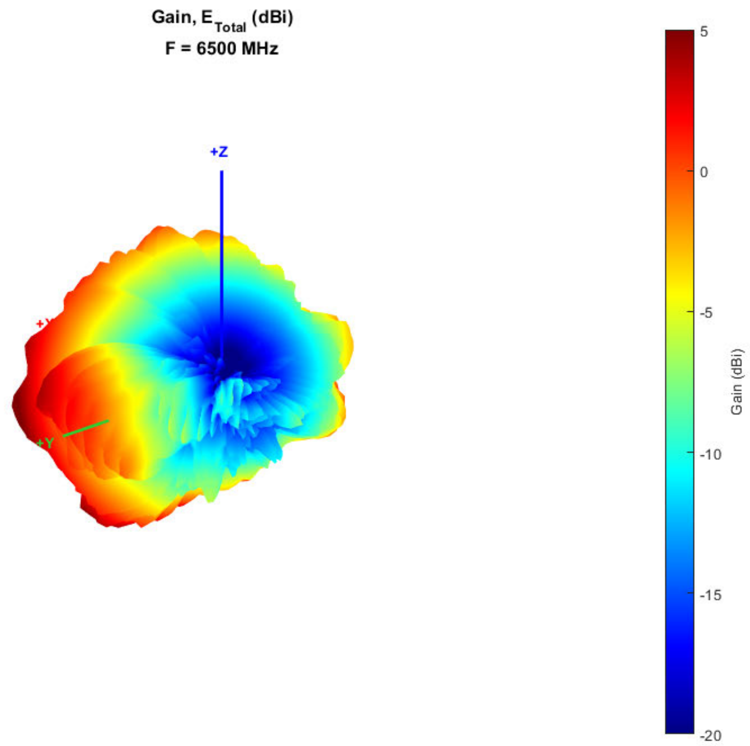
Subject A , Right Waist, Horizontal Antenna Top



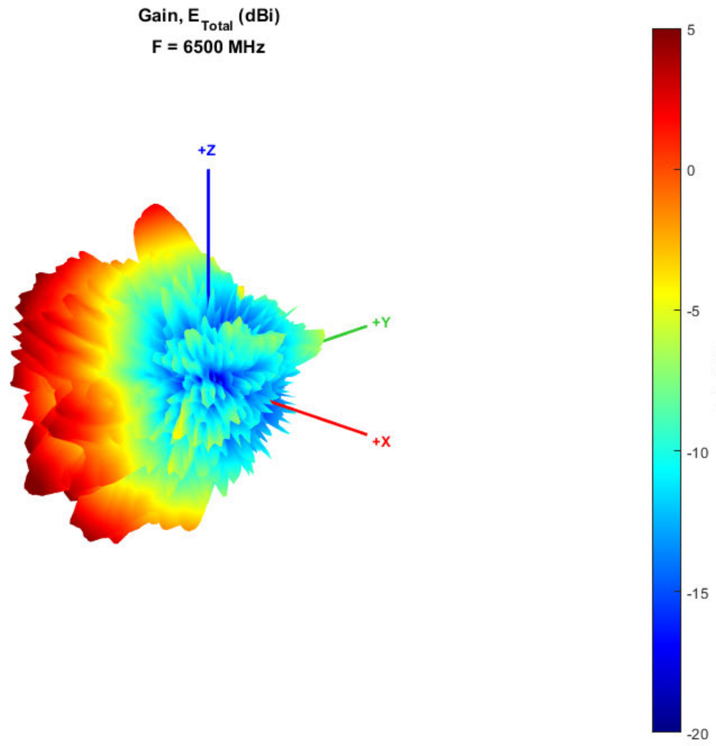


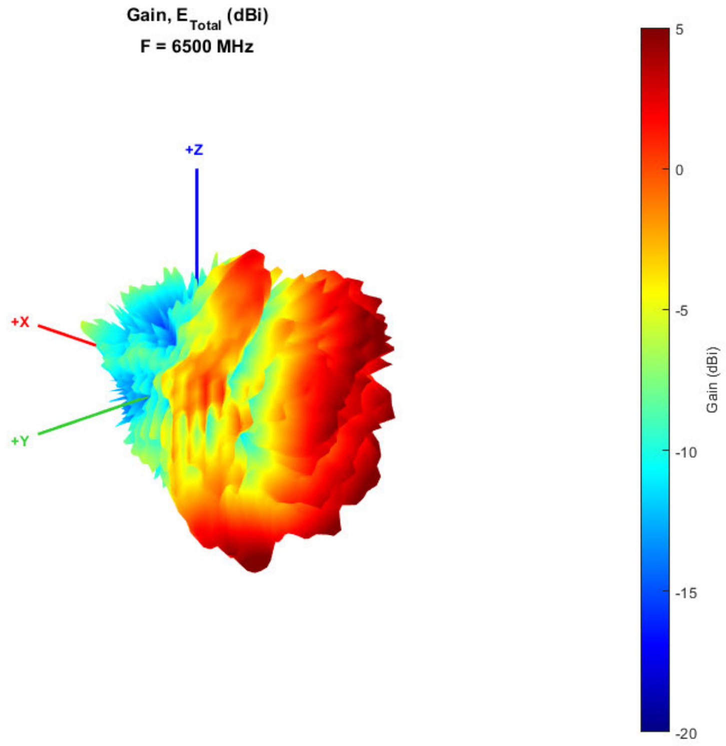
Subject A , Right Waist, Horizontal Antenna Bottom



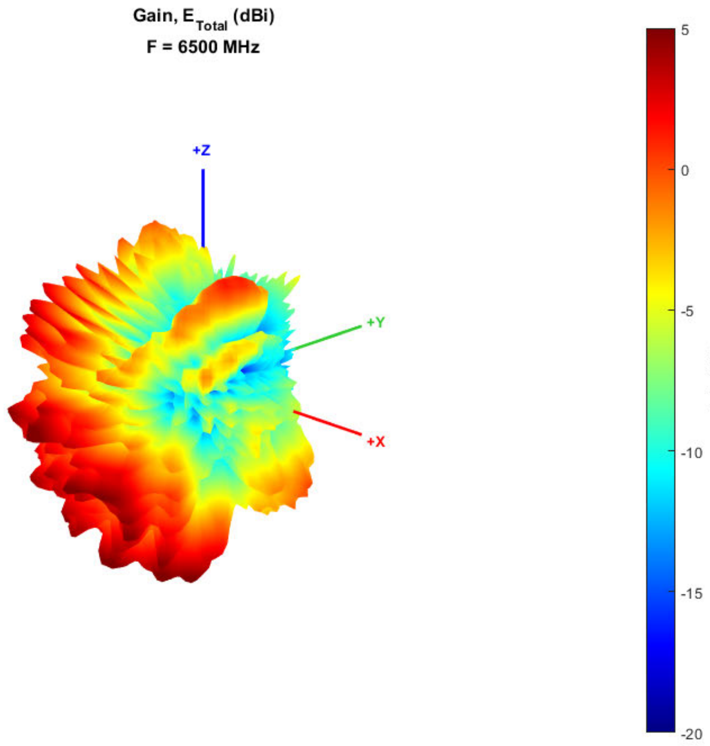


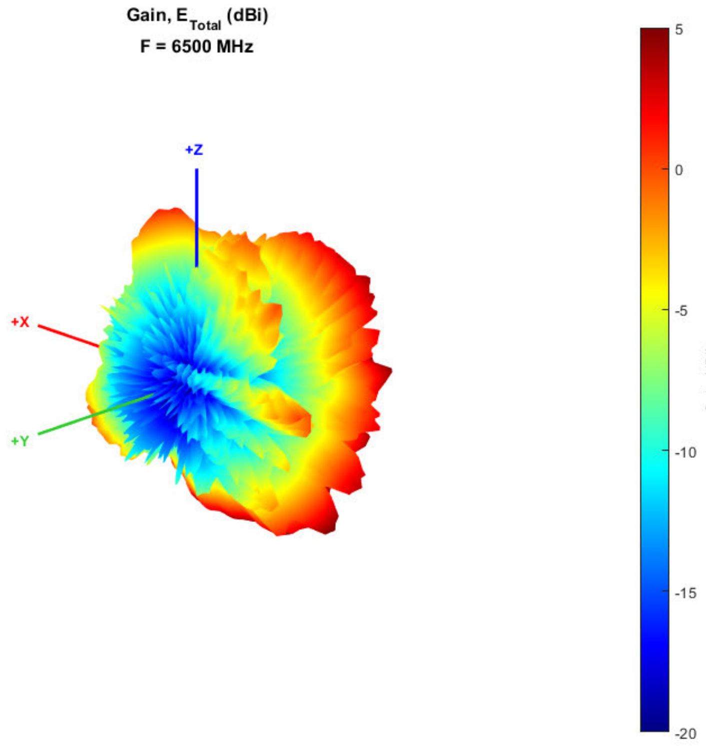
Subject A, Left Back Pocket, Vertical Antenna Top



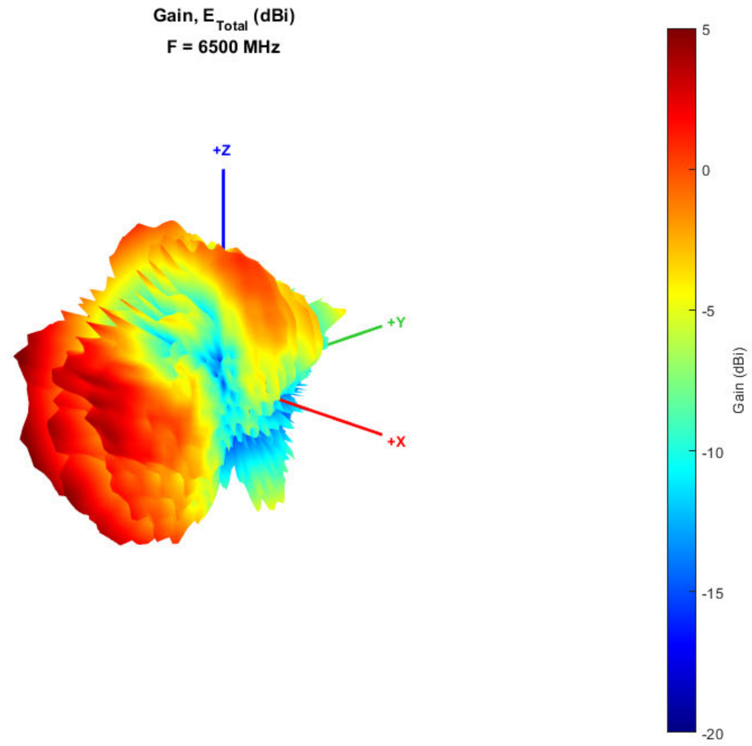


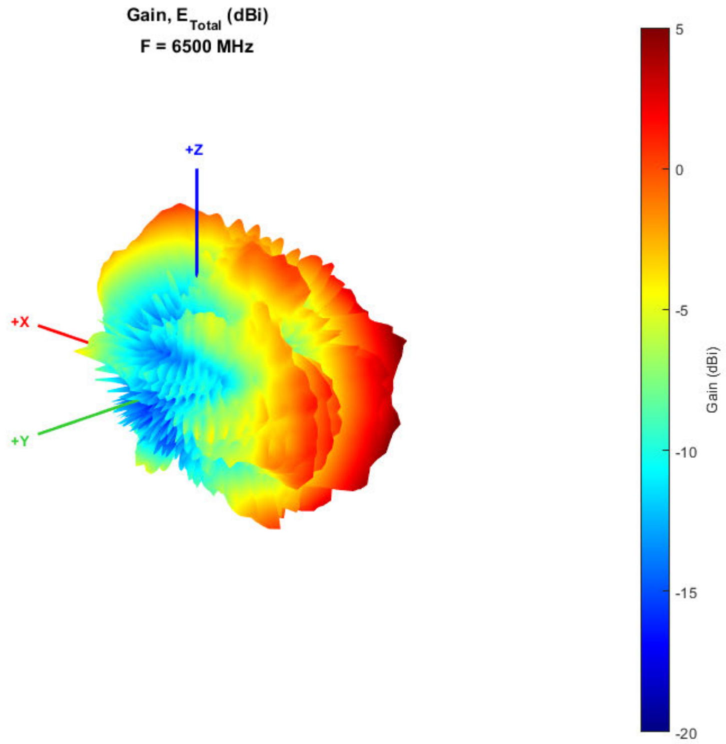
Subject A , Left Back Pocket, Vertical Antenna Bottom



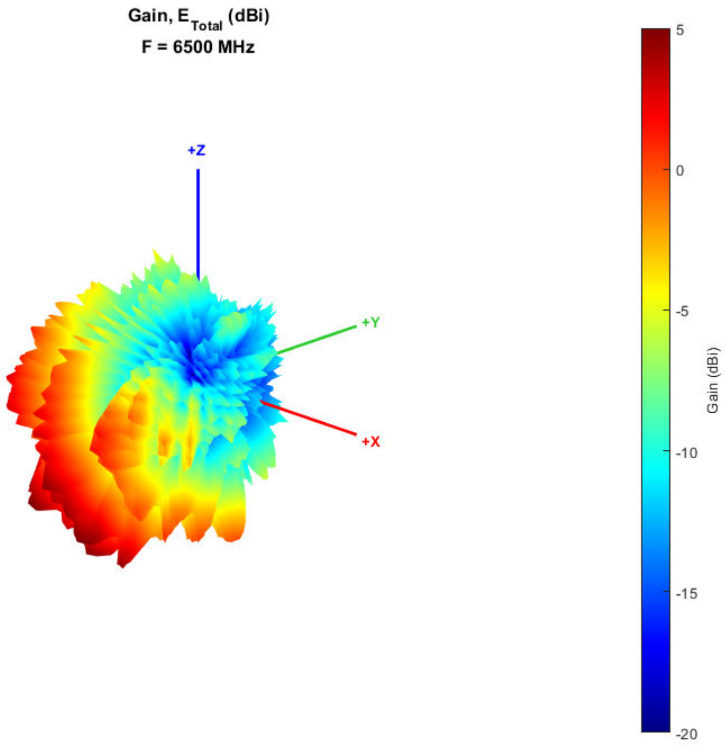


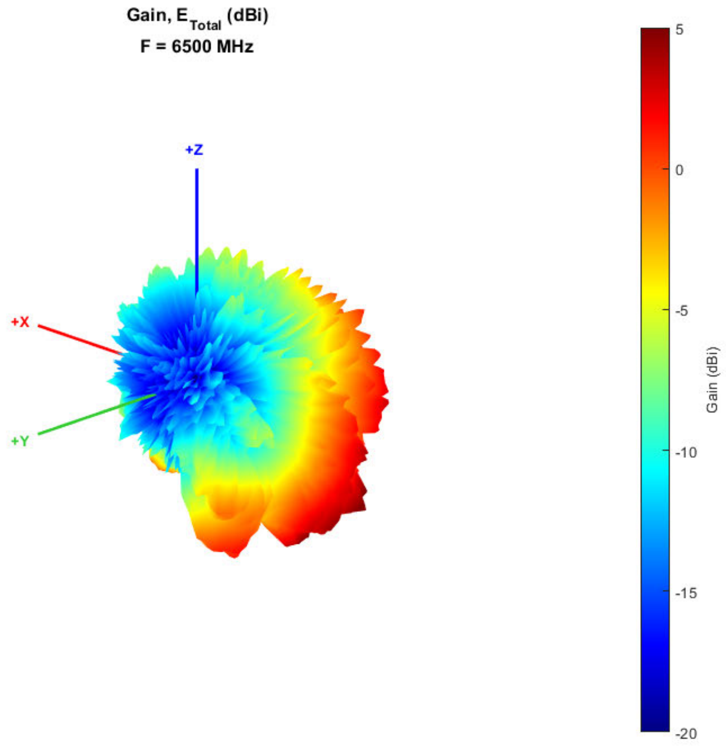
Subject A , Left Back Pocket, Horizontal Antenna Top



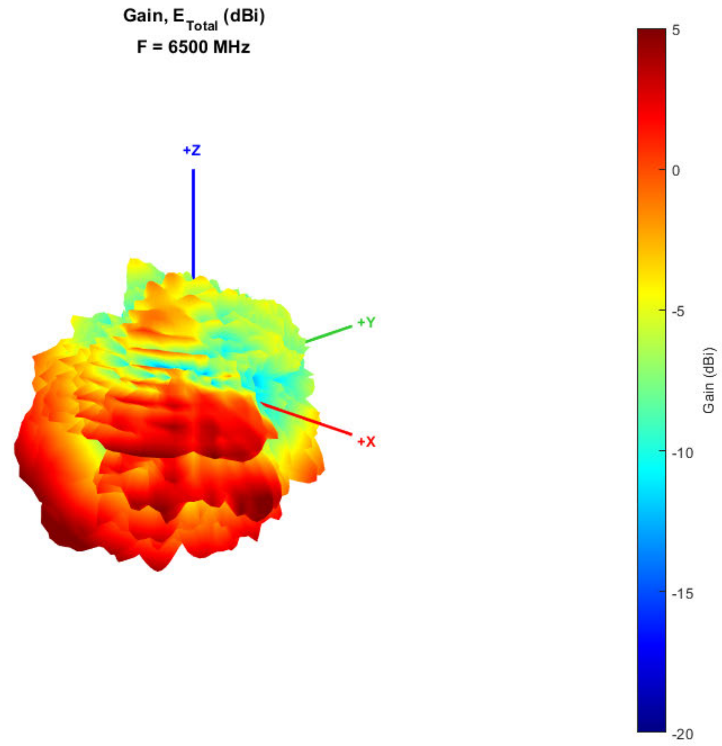


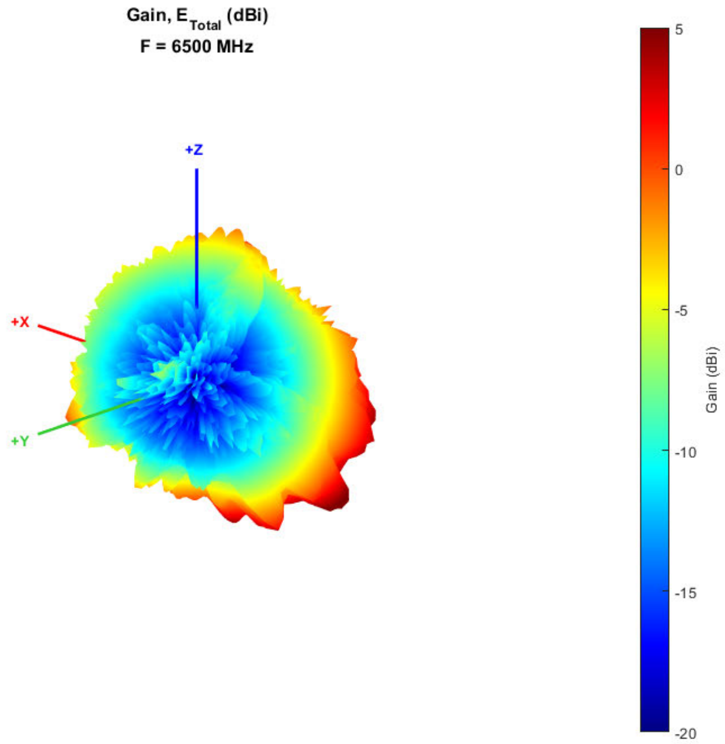
Subject A , Left Back Pocket, Horizontal Antenna Bottom



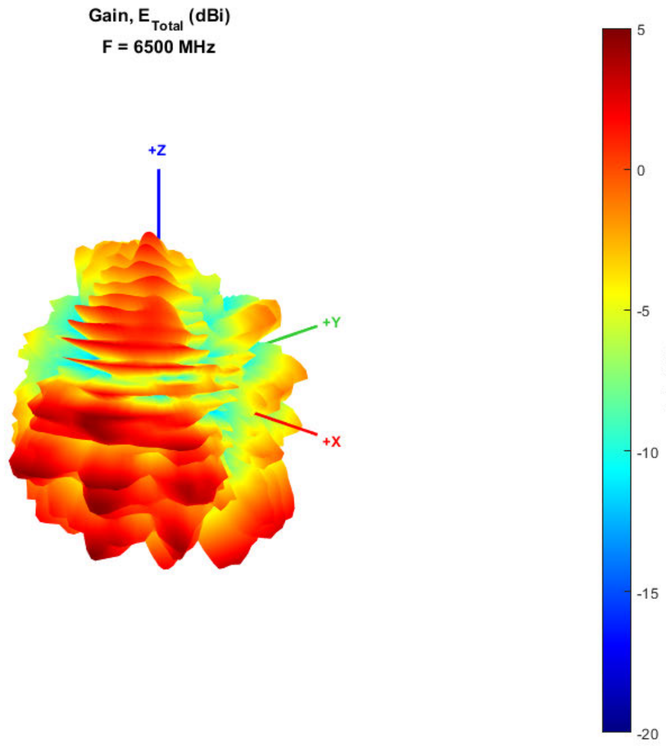


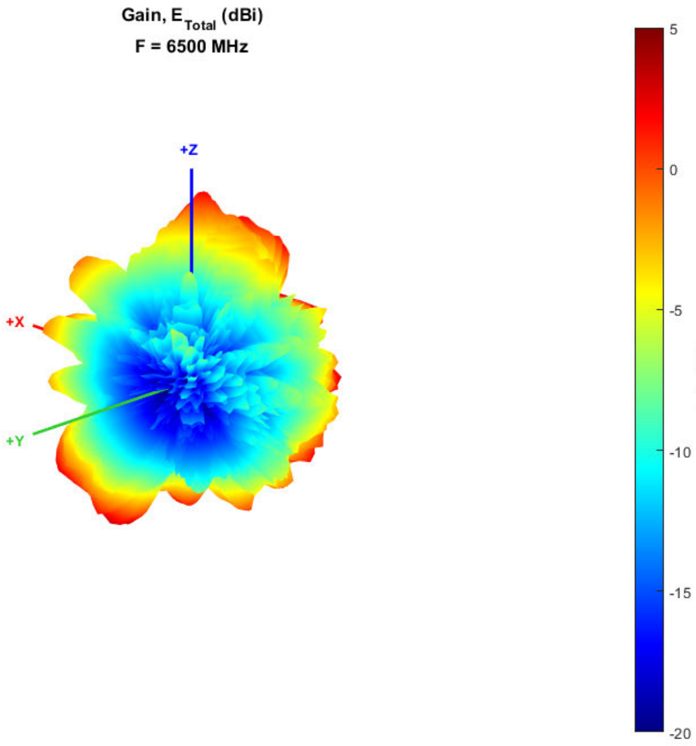
Subject A , Right Back Pocket, Vertical Antenna Top



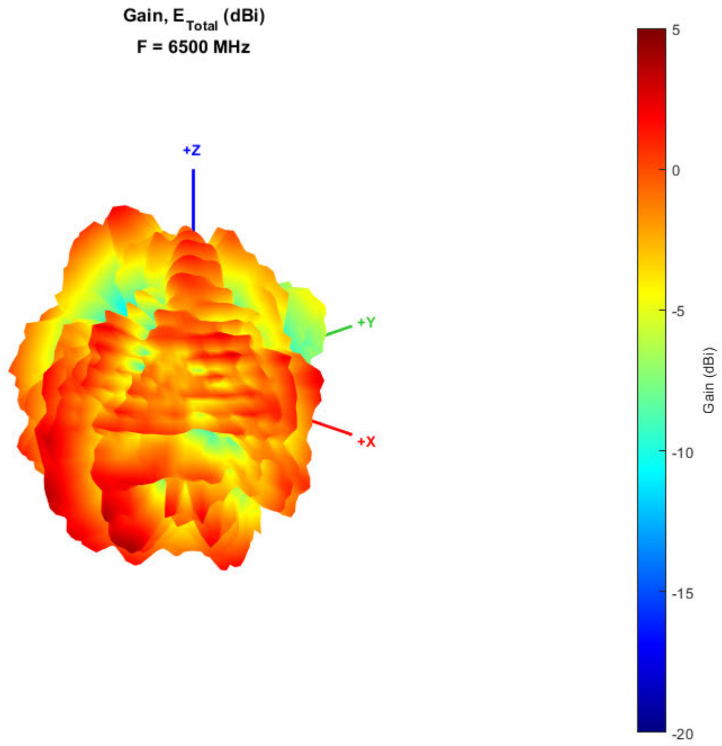


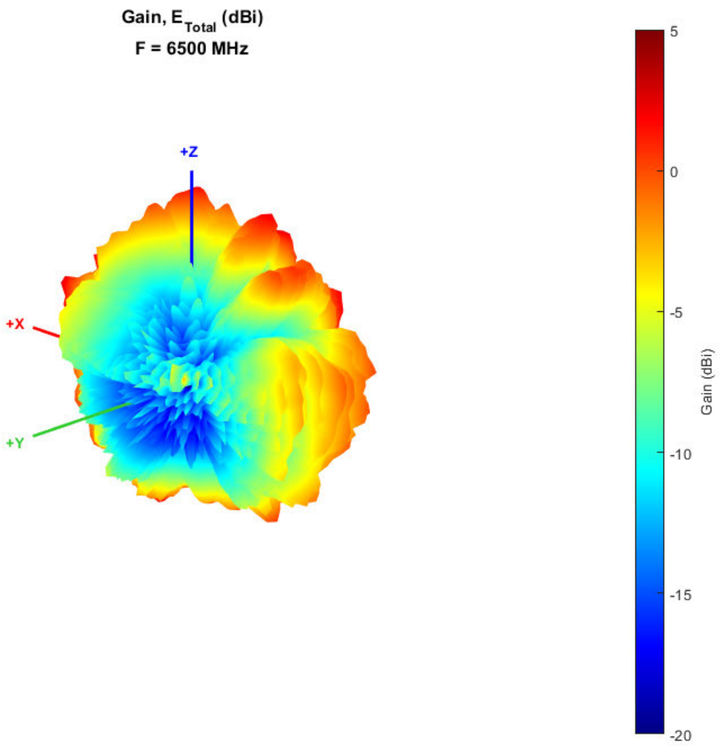
Subject A , Right Back Pocket, Vertical Antenna Bottom



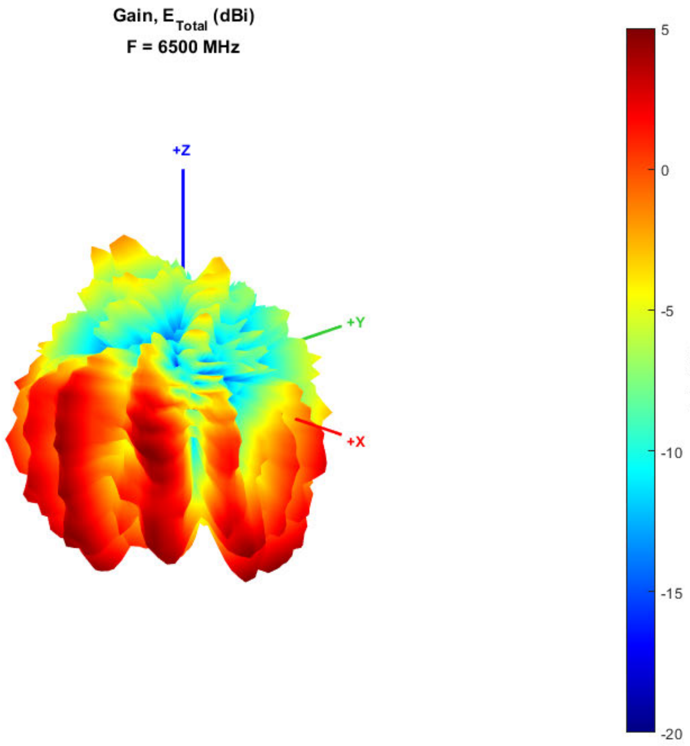


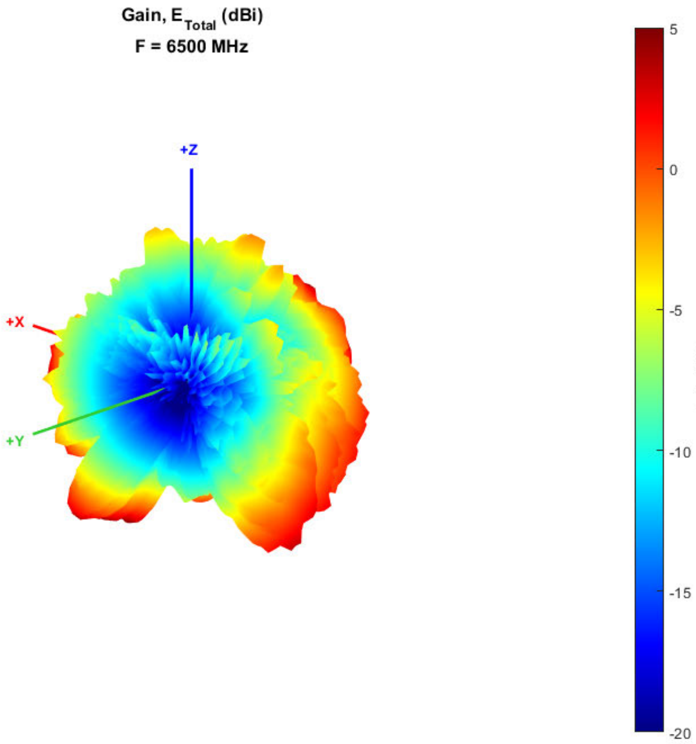
Subject A , Right Back Pocket, Horizontal Antenna Top



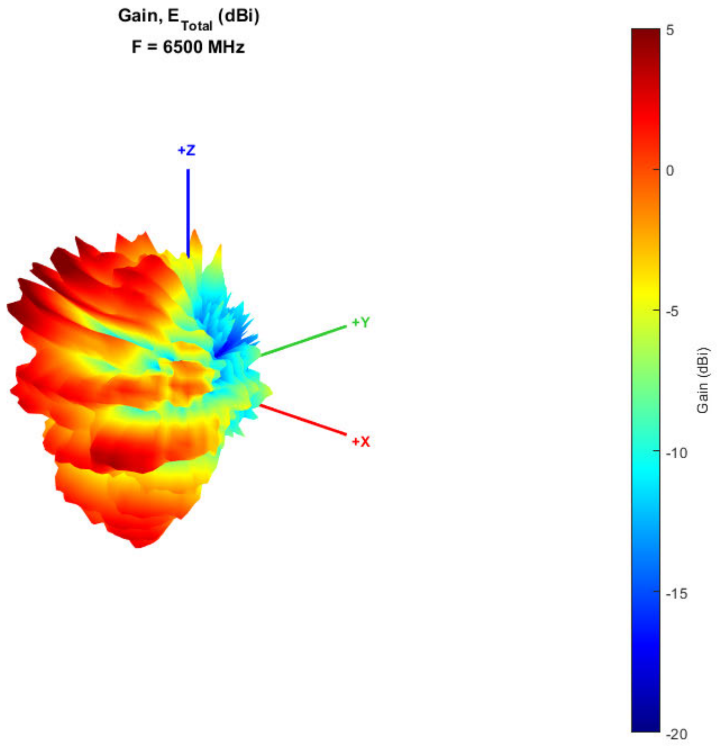


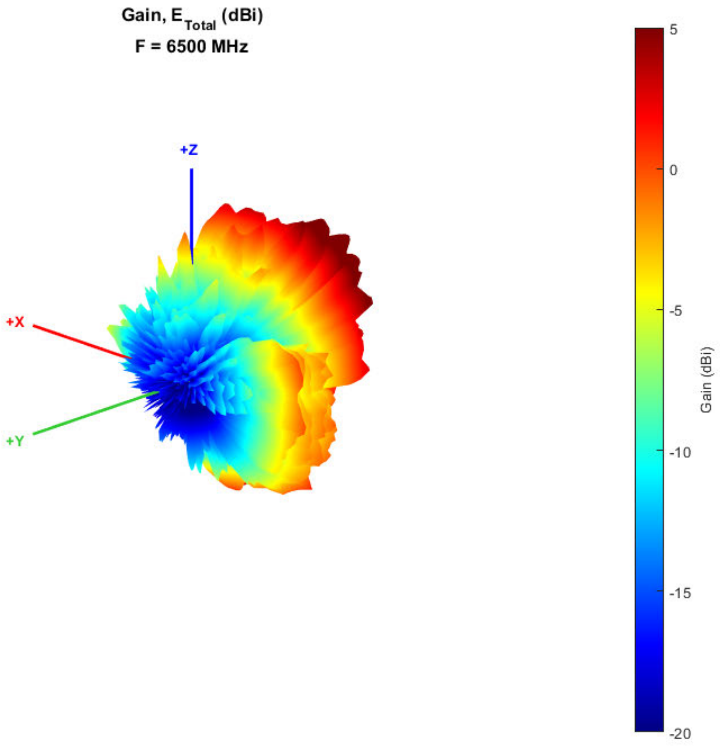
Subject A , Right Back Pocket, Horizontal Antenna Bottom



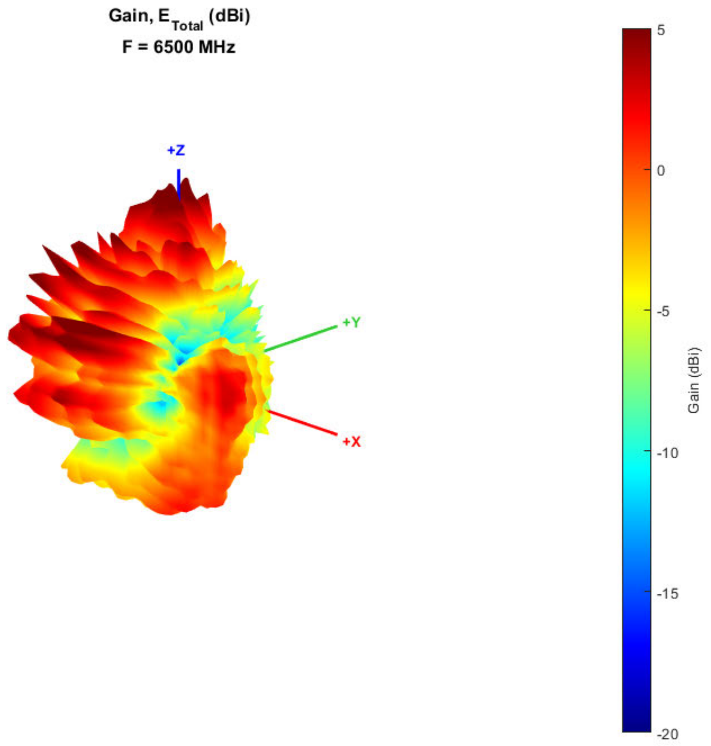


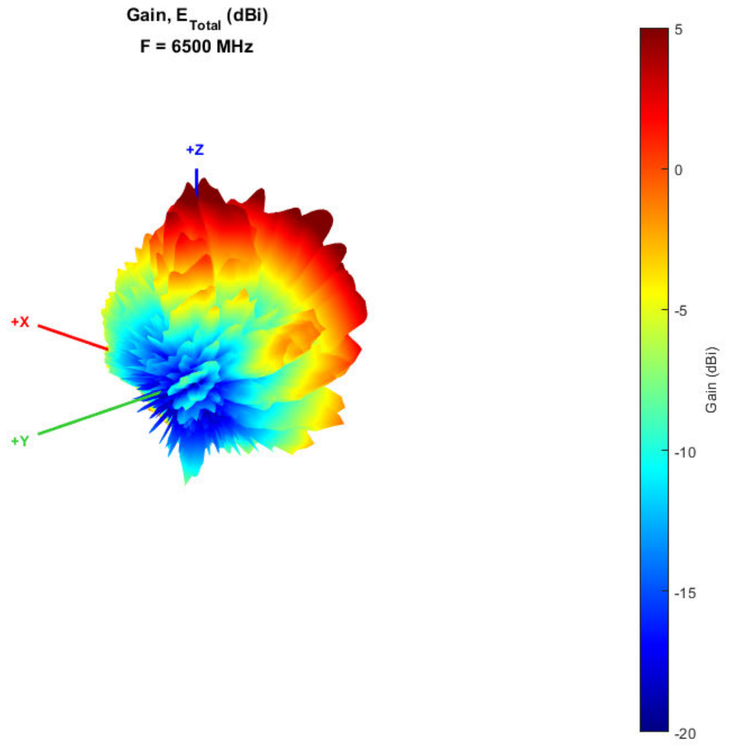
Subject A, Backpack, Vertical Antenna Top



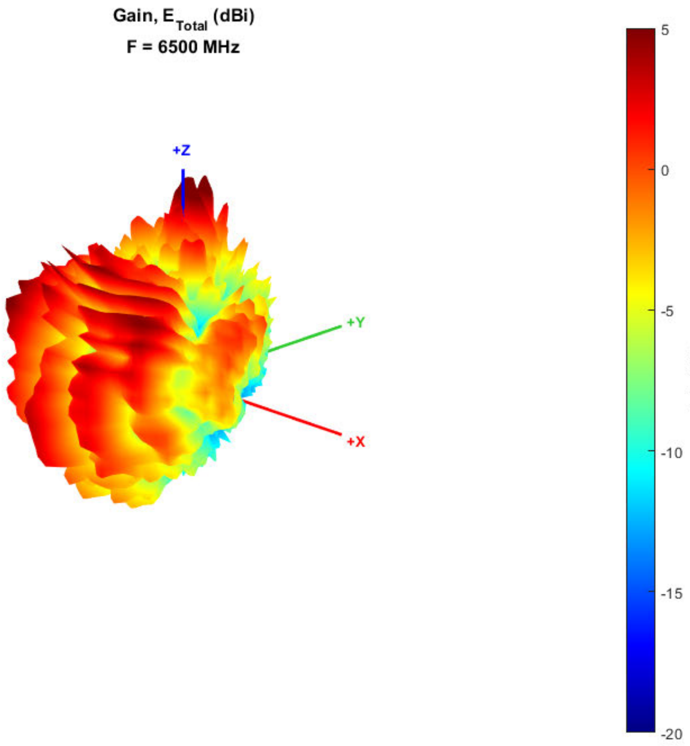


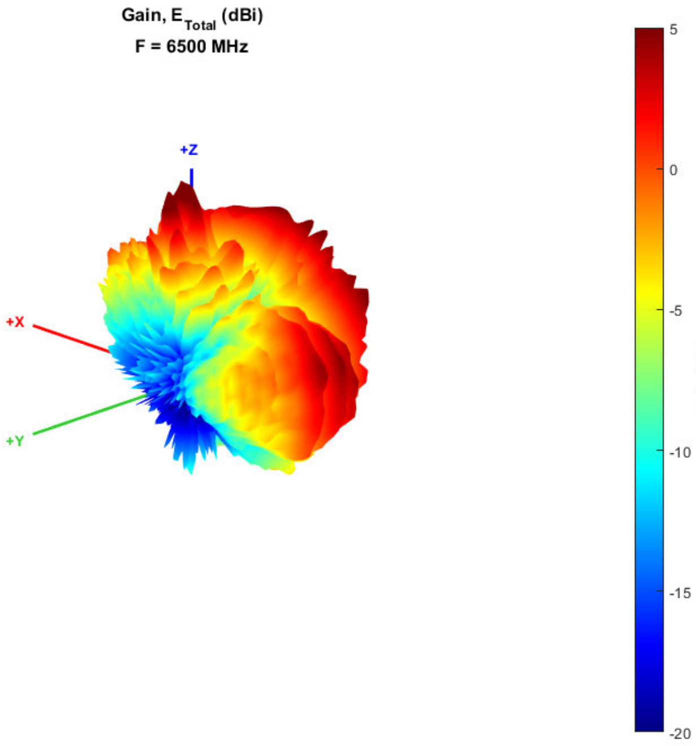
Subject A , Backpack, Vertical Antenna Bottom



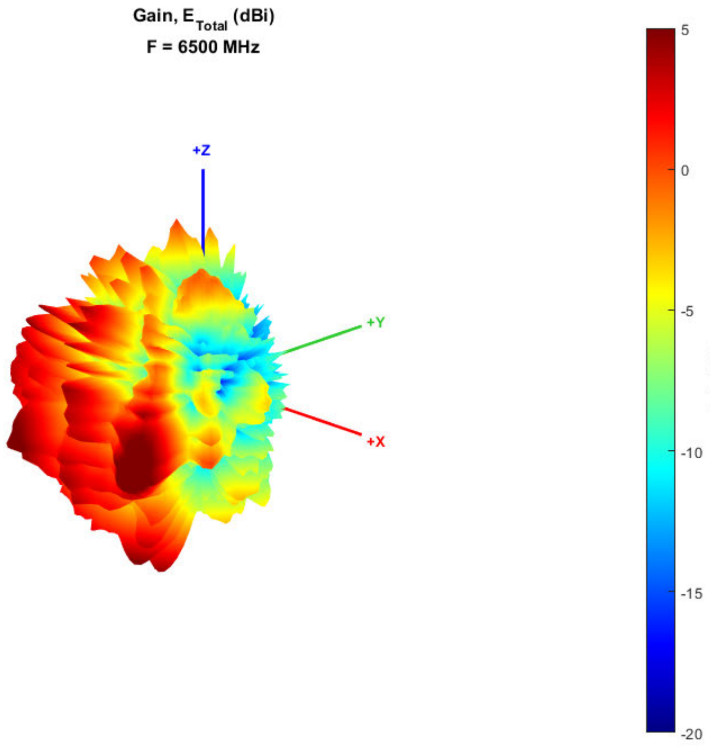


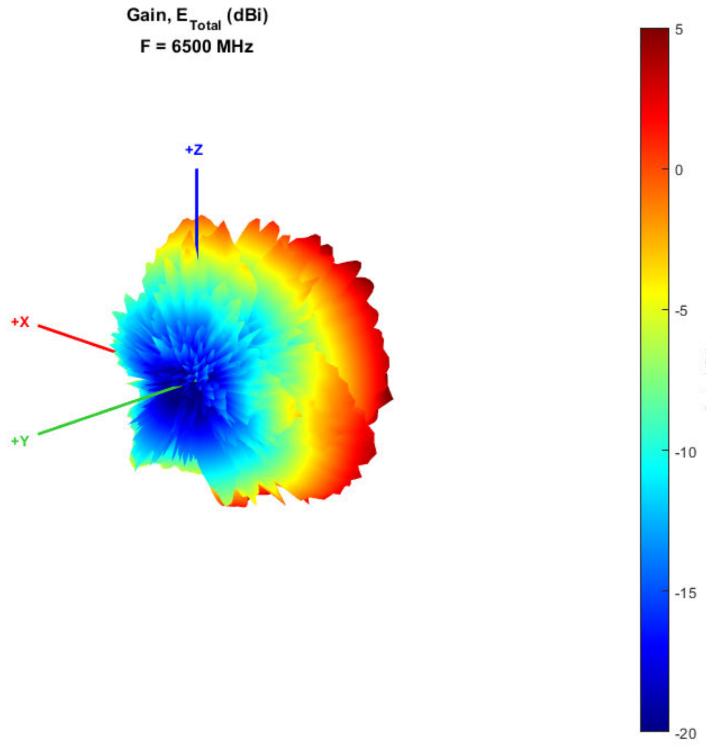
Subject A , Backpack, Horizontal Antenna Top



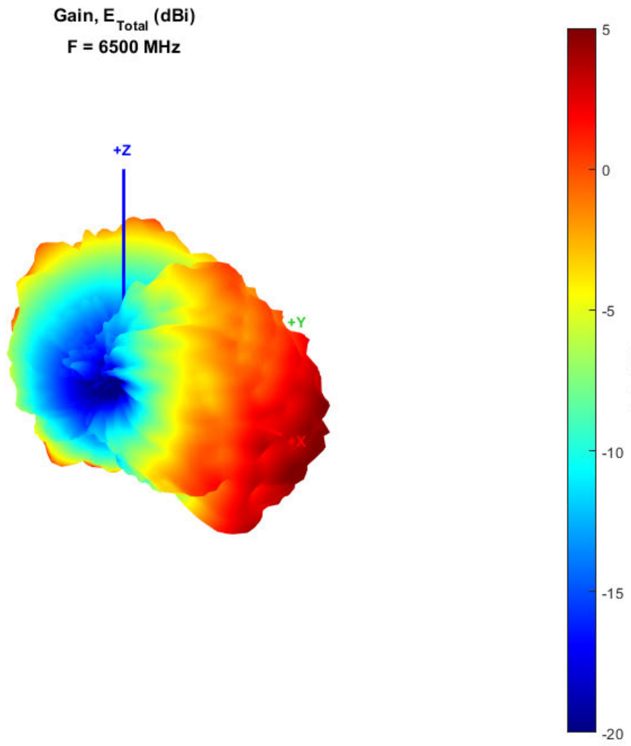


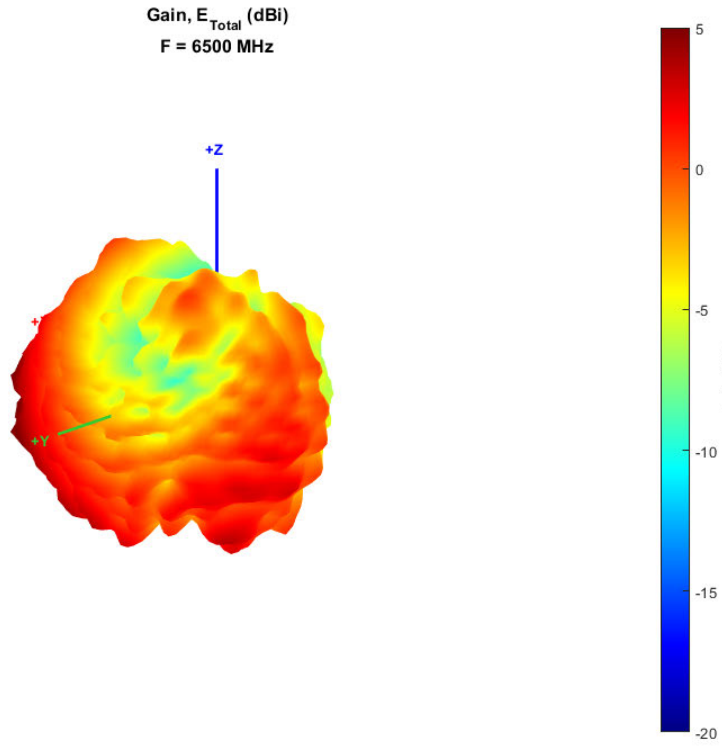
Subject A , Backpack, Horizontal Antenna Bottom



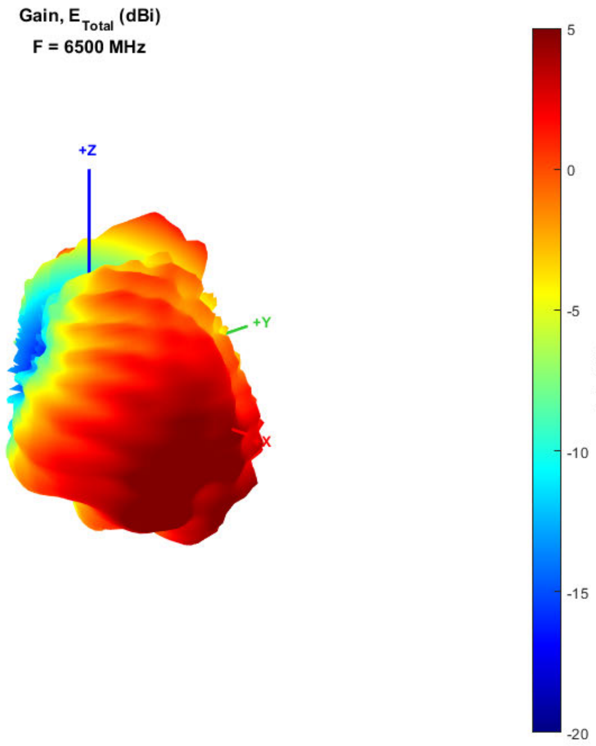


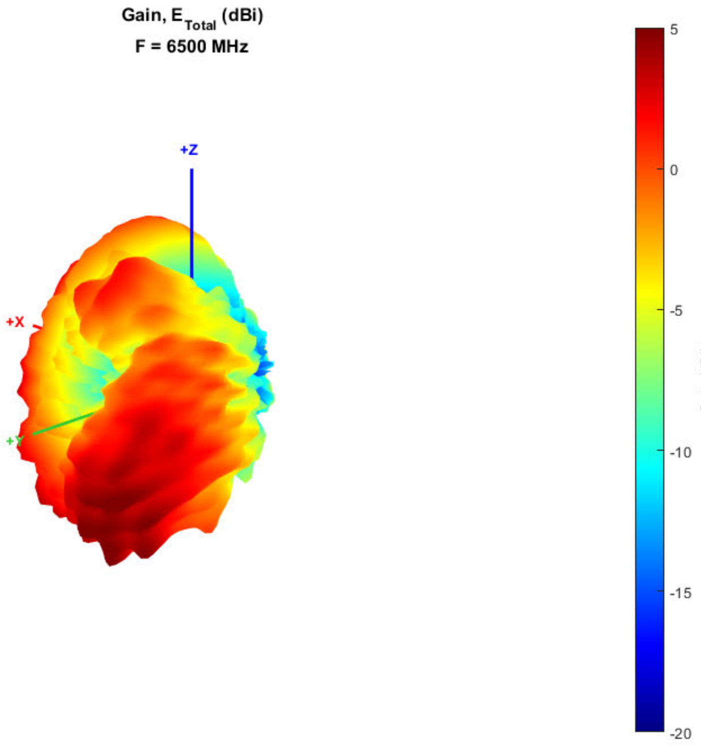
Subject A, Glasses, Head Pointing Left 45 degrees





Subject A, Glasses, Head Pointing Forward





Subject A, Glasses, Head Pointing Right 45 degrees